FOURTEENTH ANNUAL DINNER.

THE fourteenth Annual Dinner of the Institution was held at the May Fair Hotel, London, on Friday, October 29, 1937. The Right Hon. Lord Nuffield, O.B.E., M.A., D.C.L., President, was in the chair. The attendance numbered over 400 members and visitors.

Among those present were : The Rt. Hon. Sir Thomas Inskip, P.C., K.C., M.P. (*Minister for the Co-ordination of Defence*) ; The Rt. Hon. Lord Austin, K.B.E., LL.D., J.P. (*Past-President*) ; The Rt. Hon. Lord Sempill, A.F.C. (*Immediate Past-President*) ; The Rt. Hon. James McMahon, P.C. ; Mr. J. W. Dulanty, C.B.E. (*High Commissioner, Eire*) ; Engineer Vice-Admiral Sir Harold A. Brown, K.C.B. (*Director-General of Munitions Production to the Army Council*) ; Mr. J. H. Bingham (*Chairman of Council*) ; Sir Walter Kent, C.B.E. (*Past-President*) ; Lieut.-Col. H. A. P. Disney (*Director of Aeronautical Production, Air Ministry*) ; Sir George Lee, O.B.E., M.C. (*President of the Institution of Electrical Engineers*) ; Major-General S. Capel Peck (*President of the Institution of Automobile Engineers*) ; Mr. Alan E. L. Chorlton, C.B.E., M.P. (*President of the Institution of Engineers-in-Charge*) ; Mr. W. Walker (*President of the Institute of Cost and Works Accountants*) ; Mr. Tom Thornycroft (*Past-President*) ; Mr. J. D. Scaife (*Past-President*) ; Dr. H. Schofield, M.B.E. (*Principal, Loughborough College*) ; Mr. C. le Maistre, C.B.E. (*Director, British Standards Institution*) ; Air-Commodore J. G. Hearson, C.B., C.B.E., D.S.O. (*Air Officer Commanding the Balloon Barrage Group, Fighter Command*) ; Mr. C. Witham (*Director of Industrial Planning, War Office*) ; Mr. C. Stucke (*Assistant Director of Industrial Planning, War Office*) ; Mr. C. J. Bartlett ; Mr. G. E. Bailey ; Mr. F. T. Hearle ; Mr. W. A. Clapham ; Mr. H. W. Stuchbury (*War Office*) ; Mr. Alfred Ewing ; Mr. W. T. Bell ; Mr. H. D. Tollemache ; Mr. P. W. Smith, O.B.E. (*Chief Inspector, Engines, Air Ministry*) ; Mr. H. A. Darling (*Chief Structural Engineer, Office of Works*) ; Mr. C. Edgar Allen (*Editor, " Machinery "*) ; Mr. I. W. Chubb (*Editor, " Machinist "*) ; Mr. H. Syrett, C.B.E., L.L.B. ; Mr. A. C. Keen ; Dr. John F. Crowley ; Dr. H. B. Morgan ; Mr. J. H. Barber (*President, Sheffield Section*) ; Mr. H. W. Denny (*President, Southern Section*) ; Mr. G. C. Detlefsen (*President, Eastern Counties Section*) ; Mr. F. Grover (*President, Yorkshire Section*) ; Mr. B. C. Jenkins (*President, Luton Section*) ; Mr. J. B. Lang (*President, Glasgow Section*) ; Mr. W. Puckey (*President, London Section*) ; Mr. F. A. Pucknell (*President, Manchester Section*) ; Mr. T. Fraser (*Past-*

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The toasts of "The King" and "The Queen, Queen Mary, and the other members of the Royal Family" were proposed by the President and duly honoured.

THE RIGHT HON. SIR THOMAS INSKIP, P.C., K.C., M.P. (*Minister for the Co-ordination of Defence*) in proposing the toast of "The Institution" said: My Lord President, My Lords and Gentlemen, there is an impression in most quarters that there are two classes of the community that above all others like to talk. One class is the Member of Parliament and the other class is the Member of the Bar, and I suffer from the defects, whatever they are, of both these classes; but whatever desire I had for loquacity has long since been quenched since I assumed the duties of my present office, when I found that I knew so little about the things that most of the people with whom I have to deal knew everything about. If ever I felt embarrassed in addressing an audience it is this evening, especially after Lord Nuffield told me what he allows me to repeat—that this room represents the best collection of brains that London could produce at any given moment. Well, that does not make a very good beginning for me, and when I see you in front of me and, in addition, have reason to believe that everything I say will be taken down in writing and used in evidence against me, I am more frightened than ever. I may, however, say that if there is any company that could unlock my sealed lips it is a company of production engineers, for I have at last learnt that just as the last war was largely, on the supply side, a question of production, so any war that may unhappily overtake us in the future is likely to accentuate that feature of supply. Planned production to-day

in this highly mechanised age is more than ever indispensable in any well managed factory. The Institution of Production Engineers, which I have the honour to toast, has manifestly a most important part to play in the preparation of, or, rather let me say, in the carrying out of the programme which the Government have been forced, with the consent of the whole nation, to undertake.

In attempting to get that programme carried out with expedition and with advantage to the country, I have had to bear in mind that there are two or three conditions that must never be lost sight of otherwise our whole purpose would be defeated. The first is that we must carry out this programme in the peaceful conditions in which we are fortunately living, with a view to being able to obtain the maximum of potentiality if we were forced into the conditions of war. That necessitates that we should use the firms that have the technical efficiency that will enable them to spring into quick expansion if an emergency should overtake us; at the same time, contary to the impression which a great many people who write to me inviting orders for their particular firms seem to have, we have to avoid the loss of efficiency which would most certainly be the result of spreading unduly widely the orders that we are in a position to place. Gentlemen, if I have correctly stated one or two of those objects which as I say we must bear in mind, it is quite obvious that we shall never get the production which in Whitehall we want to see unless we have the help of gentlemen like yourselves, who understand the way to produce so as to get the maximum production out of the means at your disposal.

One of the obvious difficulties of the maximum of production, of course, is the provision of the machine tools which are the true bottle-neck to any production on a large scale, and I want to take the opportunity here this evening of refuting, if that is not too strong a word, a statement that was made in another place, which I will not specify at this moment, as to the inefficiency of the machine tool industry in relation to the Government programme, as evidenced by what was said to have been an influx of foreign machines. Gentlemen, I think I speak with the knowledge, and I hope the assent, of the great majority if not all of you here present to-night in saying that the Machine Tool Manufacturers' Association with great public spirit have consented to an admission of such foreign machines as are necessary and have in so doing acted in a way which is greatly in the public interest and has certainly earned my personal gratitude. I had the great pleasure a few days ago of going through the five or six shadow factories that have been put up by eminent firms, a most important example of which is Lord Austin's at Birmingham, and I was immensely struck by the fact that whereas twelve months ago those great shops were not even begun to be erected, to-day they are up to 75 or 80% equipped with the necessary machine

tools. I think that is a great testimony to the efficiency of the organisation which has been responsible for that part of our programme.

Gentlemen, both in connection with machine tools and in the use that is to be made of them, it is the production engineers that we must ultimately depend upon for that efficiency which is so desirable and for which I look and almost pray every day of my life at the present time ; and let me say that I have reason to be grateful to those who have lent their brains to their country's service in this present emergency. I never have reports which do not show that nearly everybody has bent all his powers upon the execution of the task that in circumstances of great difficulty we have been called upon to undertake.

Let me remind myself at any rate, though you know it far better than I do, that when this programme was first prepared, I think I may say the engineering industry had but slightly, only slightly, recovered from the depression under which it had suffered for many years, and to spring into the vast activity which is now evidenced all over our country within the space of a year or two is a wonderful achievement on the part of this great and essential industry. Gentlemen, it is largely to you that the credit must be given for this achievement.

There are just one or two points that I want to add to this brief tribute to your Institution and its members. I am well aware that from day to day one of the things that hampers production is the difficulties that arise from design. I apprehend that I shall not be making a great mistake if I say that to some extent the success of our joint endeavours must depend upon the closeness of association between the designer and the production engineer. Now, if you were engaged in carrying out the orders in what I may call normal industry, it would no doubt be easy for you in your several capacities to bring to bear upon designers the influence which you think necessary in order that you may secure the comparative simplicity which will assist production : but I realise that in the case of a Government Department—and if Admiral Sir Harold Brown sitting next to me will forgive me for saying so, a Government Department is not always the easiest organisation in the world to whom to make suggestions—it may perhaps seem to you that you must take whatever design is placed before you, whether it means unnecessarily complicated jigs or tools or arrangements. Now, with such responsibility as I have, I do beg that you will allow no hesitation to prevent you with your manifold experience from making whatever suggestions seem to you to be necessary to Government Departments with a view to simplifying design as far as possible, and also with a view to avoiding the constant alteration and adjustment of design which inevitably interferes with production. I

infer from your assent to what I last said that you have had some occasions on which to regret that you were not both designers and production engineers, but every man has his part, and I should like to pay a tribute also to the ingenuity of those who are producing the designs that are giving us at the present time equipment in all three services that is not merely second to none in the world, but is I believe superior to the equipment of every other country. Like so many things with which I am daily concerned in my duties as Minister for Co-ordination, this is very largely a matter for co-operation between you and the other branches and other members of this great partnership in the execution of the Re-armament Programme.

Now I cannot teach you anything about your business, and I hope you will forgive a layman, an amateur, and a comparative ignoramus with regard to your business, I hope you will forgive these suggestions which with some diffidence I have made to you here this evening, and I would, before I have the honour to propose this toast, add one word more. We have most fortunately, most happily, now nearly passed beyond the stage of planning in the large, I might almost say, in the mass production of many of the things that are indispensable. Gentlemen, much remains to be done. I do beg and beseech you that you will in your several capacities and businesses give to the Government, as I know you have been giving and will give, the fullest use of your brains and your experience in helping each other and helping your firms, and helping the Government to get out of this great industry the maximum of efficiency. I know perfectly well that there is sometimes a temptation in a case where Government orders are not quite so profitable as some adventures in other directions, to prefer those adventures—yes, I hear some sympathetic cheers—well I am going to do you the honour of hoping and believing that you and your firms, the firms with which you are associated, will realise that however attractive other enterprises might be there is a high order of priority in the claims which the Government makes upon your skill and experience. I hope that at any rate the result of the visit which I have had the honour to pay to your Institution this evening will be that we shall increase production and efficiency.

Well, now, gentlemen, I have the honour after making these few observations to propose to you the health of the Institution. Your duty is to make two blades grow where one grew before, and if any man has succeeded in doing that it is Lord Nuffield. You have had some very distinguished Presidents. An Institution as young as yours that has had Lord Austin, Sir Walter Kent, Sir Alfred Herbert, and then Lord Sempill, and now Lord Nuffield as its Presidents is obviously either a very powerful organisation or a very deserving one. Well, let me believe as I do that it is a very deserving one. I

am sure that there is nobody in this room, and I think I might say in this country, who represents so well as Lord Nuffield that capacity for adventure and that thorough-going determination to succeed which has made his name a household word ; and might I presume to add to that inadequate tribute to a great personality, one other word : there is only one toast when we never make a speech and that is the toast of His Majesty the King, for the toast speaks for itself ; it would be a pity for me to spoil this toast by attempting to say any more about the man who better than most of us speaks for himself by his actions. Gentlemen, I give you the toast of "The Institution," coupled with the name of your President, Lord Nuffield.

The Rt. Hon. Lord Nuffield, O.B.E., M.A., D.C.L. (*President*) replying to the toast said : Sir Thomas Inskip, My Lords, and gentlemen, I can assure you it gives me the greatest pleasure to be here this evening, and to hear from a Minister words such as we have heard to-night. His remarks must cheer the hearts of those production engineers who can look back to 1914 and remember the great trials and tribulations in production engineering we went through during the war.

It is difficult for me to stand here to-night and to talk to such a gathering of brains as I have before me this evening. As you know perfectly well, I am not a technical expert. I can only profess to be a practical engineer. But, gentlemen, I am speaking with all seriousness, because I have, not many seats away from me, Lord Austin who combines both qualifications. Lord Austin is a wonderful engineer, and the motor industry of this country has to thank him for quite a great deal.

Now, we will go back to the Institution of Production Engineers. I think it may be said that it is generally better to start from the bottom, and therefore, I am hoping that there is some idea in this Institution of helping the apprentices, who, I understand are allowed to join this Institution as graduates. I am afraid that apprenticeship in this country has been forgotten. When one thinks of the past, an engineer always served an apprenticeship before obtaining a job. I happen to have been born an engineer, and had no apprenticeship. I feel the lack of that even at the present time. I can only hope that apprenticeship in the future will be fostered, because it is dying away very fast. I believe that it is only the tool maker and stonemasons who foster apprenticeship at the present day.

But, gentlemen, going on from the apprentice, we get to the people, such as yourselves, who are doing their best to foster production. To-night, I should feel that I had left something undone if I did not mention the name of Lord Sempill, who has done so much for this organisation. In him you have not only a highly

technical man, but certainly one with an immense amount of experience, and in trying to follow him I feel that I have a very difficult task. I can only hope that when my term of office is finished, this Institution will find a better man than myself as President—one who can talk to you in technical terms, and what is more, endeavour to the best of his abilities to do all he can to enhance production.

I would like again to praise the speech of Sir Thomas Inskip, to which you have already listened. In his position he has done his best to understand our difficulties—goodness only knows we have plenty of them. He has realised them, and he has also asked the Government to help us to get over those difficulties. My experiences of the Governments of the past—and I am going back quite a long time before the war—is that they would not listen to such people as ourselves. We were really non-existent until we were wanted to produce something, then we were really wonderful. They stroked our backs and we purred like kittens—but we purred because we had to. I remember my experiences in the early part of the war, when I was asked to produce Sinkers for the North Sea Mine Field, and I think of all the difficulties I had in producing those Sinkers, but I am sure my greatest difficulties were in dealing with the Government. I will add that my experience since the war is that all that has changed, and I can say we have had the greatest assistance from those gentlemen in the present re-armament scheme. They ask us tc do all we can, and they will, in return, do all they can to get together with us to produce the articles which are required. That is the feeling we are looking for. Had that happened before the war, believe me, the war would not have lasted as long.

Sir Thomas has asked you to help, and I am sure that when the occasion arises, everyone in this room will do his level best for the old country. That is all that matters. When, after my many travels around the world, I come back to the old country, I do not think I am mistaken in saying that it is still the *only* country in the world.

There is so much talk to-day of a boom in this country. Gentlemen, it is not a boom. It is only what we deserve. Nothing annoys me more in this world than for people to call this a boom. We are busy, for Heaven's sake why should not we be busy ? We were the first people in the world who discovered how to produce steel, and we taught the rest of the world how to produce it, but we have forgotten how to go on producing it in sufficient quantity for our own requirements. We cannot get on with our jobs owing to material shortage, but anyway, I think we can promise the country and the Government that as soon as they will give us the proper steel and the proper tools, the British workman will machine cheaper than anyone else in the world.

You will have heard enough of me for this evening, and in replying to the toast, may I say how much I appreciate Lord Sempill's insistence that I should become President of this Institution. You would not believe the amount of pressure he used. I did try to get out of it, but he would not let me. I will say, however, that it is a pleasure for me to be here to-night as your President and I hope that all the boys in this room, whenever called upon to do a job of work, will put out their best endeavours, and if they do that God help the rest of the world.

At the conclusion of his speech, the President presented awards as follows : *Medal for Best Paper* 1935-36 *Session :* To Mr. W. Puckey, President of the London Section, for his paper on "Personal Problems of Management."

Medal for Best Paper 1936-37 *Session :* To Mr. H. C. Town, Yorkshire Section, for his paper on "Hydraulic Operation of Machines."

Hutchinson Memorial Medal, 1936-37 *Session :* To Mr. A. E. N. Bolton, for best paper by a Graduate, "Stressed Wood Construction"

THE RT. HON. LORD AUSTIN, K.B.E., LL.D., J.P. (Past President) in proposing the toast of "The Visitors," said : My Lord President, My Lords, and Gentlemen, it is my privilege to-night as a Past-President to propose the toast of "The Visitors," and I do so with very great pleasure, seeing so many old friends of the Institution amongst them. We have also many new and distinguished guests, and to them I extend a very hearty greeting on behalf of the Institution.

For the past few years we have seen the work of the production engineer growing in importance, until to-day he is looked upon as the one man who can overcome many of the difficulties which beset, not only this country, but the rest of the world. Without his aid most of the amenities of life would not exist—motor-cars, wireless, aeroplanes, refrigerators, etc.—you notice I put motor-cars first. It is most gratifying to me to see the present satisfactory position of the Institution, for I have watched its progress with interest for the last fifteen years. When I look back on its first days I cannot help comparing those early meetings with this splendid gathering to-night. Fifteen, even ten, years ago the numbers present at our Annual Dinner were only a mere handful, and more than once I constituted almost the entire guest list ! To-night when I see the long list of distinguished visitors who have honoured the Institution by their presence I feel proud to have been so long and so intimately connected with the development of this Institution.

Throughout its life the Institution has endeavoured to concern itself entirely with the activities of production engineering, never encroaching on the activities of kindred institutions, but working with them in a spirit of co-operation and helpfulness. If any proof

were needed, of the ramifications and importance to industry of the Production Engineer, a glance at the names of the Institution Presidents would provide it. Reviewing the names over the past ten years you find Sir Alfred Herbert, of machine tool fame, followed by Mr. Tom Thornycroft, representing quite another side of engineering, then myself of the motor-car industry, Sir Walter Kent, engineering, Lord Sempill, aeronautical engineering, and now I am glad to see the presidential chair again occupied by one whose interest is centred in motor vehicles, my friend, Lord Nuffield. May I take this opportunity of saying that we in the Motor Industry are very proud to have one of our number able and willing to do such wonderful things as he has done. May I on your behalf wish him long life and every possible happiness. Personally, I should also like to thank him sincerely for the very generous remarks he made about me in his speech. Coming from him I value those remarks more highly perhaps than from anyone else. I might say on every occasion when it has been necessary in the interests of the industry generally to discuss matters with Lord Nuffield, I have always found him willing and anxious to help and to do the best for industry.

I am very pleased to find that amongst our distinguished guests this evening are Sir Thomas Inskip, Minister for the Co-ordination of Defence, Admiral Brown, and Colonel Disney, Director of Aeronautical Production, for they appreciate fully, I can assure you, the important part the production engineer is playing in the Government's Re-armament Programme. Colonel Disney and I along with the five firms who head the Shadow Factory Plan, have worked very closely together through these last twelve months. I am glad to say we can now review the results with satisfaction. The new Shadow Scheme is now an accomplished fact and a great success, and the production engineer has played a very big part in the achievement. You all know how intricate and accurate the work has to be in the particular engine which is being manufactured by the Shadow group. The five firms responsible got together, built and equipped new works, and largely with your help and with the help of this Institution they have produced in a very short period an engine which on its first assembly went together perfectly and carried through its test with every success. I do not know why the "Shadow" experiment should have excited so much comment, but as a matter of fact I think results show, and I am sure you will agree, gentlemen, that if the Government have to manufacture engines in an emergency the motor-car industry could take all the responsibility attached to that work with every possible confidence.

I am glad to see, gentlemen, that my friend Dr. Schofield is going to reply to this toast. I hope he will have something to say about the Research Department which it is proposed this Institution

should set up, and which the Board of Governors of Loughborough College have so kindly offered to house free of charge. I think a Research Department would be a most useful and valuable addition to the Institution's activities, but it should not overlap nor interfere with the work done by other institutions' research departments. It should map out a programme of work which will definitely be useful to production engineers. I am afraid that it is the practice generally with research departments of institutions that there is far too much overlapping and not enough specialisation. I need hardly say that this department should be placed under the charge of a very competent person, and I know, and you know too, that it is very difficult to find such a man outside industry. I can say this, that if there is such a man at a loose end, I know where he can find a job of work. Then, gentlemen, the research department must be kept up-to-date—it must be in urgent demand and be really useful—it must be adequately supported. I am sure our institution appreciates what is necessary, but you will have to ask the industries in which you operate, and also your good friends, to come along and help, because it would be useless providing a sum less than £10,000 to £15,000 in the first year or two. It might be considerably more than that in later years.

We have not heard very much about the Institution to-night, and I would like to take the opportunity to say a few words about it. Some of the gentlemen present may not be aware of the really rapid rise to importance which the institution has made, showing that it was necessary and filled a definite want. Founded only fifteen years ago it has to-day 1,556 members and 19 local sections, and these are being added to every year.

It is interesting to note also that the first Overseas section was opened this year at Sydney, Australia.

I feel constrained to admit, gentlemen, that in the very early days of the Institution I raised doubts as to the necessity of having another separate institution. We had so many. But the answer to that is the wonderful progress which has been and is being made. At the start I strongly advised the governing body that it should follow the lead of the electrical engineers, which at that time had I believe 13 sections, and was making very rapid progress. The practice of these two successful institutions shows that it is best not to centralise in London. I am sure gentlemen, that one of the greatest reasons why the Institution has made such a big success is that you have decentralised your efforts, made the local centres interesting, and they have been visited by a far greater number of people than could possibly have visited London.

Now, gentlemen, I am sure you will be pleased to know that we have with us to-night Mr. Oscar Harmer, who is just celebrating his eighty-eighth birthday. I am quite sure we all wish him many

more years of life in which he can take part in our celebrations, and our yearly dinner. The youngest guest is, I believe, only seventeen years old, Mr. Dormer's son. Our guests to-night are so numerous that it would be impossible for me to mention all of them, but I am sure that we do feel it an honour that they are with us at our Annual Dinner. I hope that they have enjoyed themselves and that they may be able to come on future occasions. Without further ado I will ask you to rise and drink the health and success of "The Visitors," coupled with the name of Dr. Schofield.

Dr. H. Schofield, M.B.E. (Principal of Loughborough College) who responded to the toast, said: My Lord President, My Lords, and Gentlemen I am sure in rising to respond on behalf of your guests as a layman I have the sympathy of the great majority of you in this room in following three such giants as Sir Thomas Inskip, Lord Nuffield, and Lord Austin. None but an educationalist would dare to step into such a position, and I am not sure in what capacity quite I am replying, whether as an engineer or an educationalist; because you know, if for a moment I may assign to myself the educational aspect, we have our difficulties just as the production engineer has. They are rather of a different character, possibly because we have focussed upon us a much greater degree of limelight. Yes, I think so. I was introduced a short time ago by a very old friend of mine, an Oxford Don, who said, "Well, before Schofield gets up to speak, I think you ought to know that he is connected with education, and I think I ought to tell you something about education and what it is. Well, the best definitition I know of education is that it is the casting of artificial pearls before real swine." It was not very kind to the audience, and it was not very encouraging to the speaker himself, being a diffident man as he always is; and another very well-known public man a short time ago in my hearing, when asked whether he believed in higher education for young ladies, said very much to the surprise of the audience, no, he did not, because if they were beautiful it was unnecessary, and if they were not beautiful it was inadequate. I think I have convinced my critic at the opposite end of the room that the educationalist always rises under some difficulty.

Well, may I perhaps as representing an organisation the slogan of which since its foundation has been "training on production," speak to this audience without feeling quite like a lion in a den of Daniels. You know, we in Loughborough do realise the necessity of being real in our educational training, and having a realistic view point which we can put before all those who come to us for all such training. The system which I introduced into this country—and may I say introduced with the same usual difficulty which you have experienced when introducing something which you think is valuable to a Government Department—has now become firmly

established and that you, my colleagues in the production engineering industry, are simply asking for more and more, for which I thank you.

Now, I am grateful to Lord Austin for mentioning this question of the research laboratory on engineering production, and I have been very interested in the work and the pioneering steps which your Institution has taken in that matter. I think it would be true to say, although it is a contradiction in terms, and will certainly be challenged, but nevertheless it is productive of thought, that the technique and excellence of production has almost excelled the technique and excellence of the means of producing that production. I will leave you to think about that. But the suggestion which has been made that there may be an opportunity of securing the services of an international authority such as Dr. Schlesinger and establishing him in this country in charge of a laboratory for production engineering investigation and research is one which merits very caerful thought of all interested in production in its very widest sense. I am going to avoid as far as possible the atmosphere of controversy to-night, but I do not think I shall be really on controversial ground when I say that I have had some intimate knowledge of the work which Dr. Schlesinger undertook and carried out so successfully at Charlottenberg. Having regard to the work he has done and the results he has achieved, and having had to leave that and therefore being now available, it does behove some authority, and what better authority than the Institution of Production Engineers, to see that his services are utilised in this country.

May I perhaps take my cue as educationalist here and say that however good may be our present position, we can never sit down and say that it cannot be made progressively better by intensive research. We never reach finality and there are always fields to conquer ahead, and it would indeed be a very curious man, however high he were placed and whatever order or branch he represented, if he said that there was no room for further investigation and for further develpment of technique, and it is for this reason that I feel so gratified that the Institution is at any rate prepared to place its resources, its prestige, and its influence behind the task of establishing in Britain a national laboratory for production engineering investigation. Lord Austin has said, and I will repeat it, that my governing body are prepared if required to extend hospitality for such a scheme with matters of building, staff equipment, and other things of that character. We are keen, we are proud of our pioneering and we are prepared to do whatever we can if called upon. I think that you yourselves, and I am sure the Right Honourable gentleman the Minister for the Co-ordination of Defence, will be the first to admit that side by side with technical skill, actual production education can play its part, and Sir Thomas,

it *is* prepared to play its part in the hour of the country's need and to place its resources at your disposal. Now, my Lord President, I understand that if assistance is forthcoming from industries concerned, the Government itself is prepared to back this, both with its authority and with its finance. It is an excellent idea. It is something which at any rate should not be turned down without very mature thought and without very careful attention, and I do trust that the note which has been sounded tonight by Lord Austin—and it could come from no greater authority and from none with more profound experience of the necessity for it—will not have fallen on deaf ears.

We on the education side owe very much to the Institution of Production Engineers, and may I say on behalf of your guests how much we owe to the vision and to the labour of your Secretary Mr. Hazleton? I had the pleasure of meeting him many years ago, when the membership of this Institution could be counted in very small numbers, and I know something of the labours, in season and out of season, which he has put into it. He is in no uncertain measure to thank for the past success of the Institution of Production Engineers, and for whatever it may attain to in years to come it will owe to him a debt of gratitude that it can never repay.

On behalf of your guests, My Lord President, and I speak very diffidently, as I do not think I have ever replied before on behalf of a Minister of the Crown, who is much more capable of replying to this toast than I am, but on behalf of your guests, many of them distinguished national figures, we do thank you for the hospitality you have extended to-night. The fare has been excellent. The speeches, coming from the men from whom they have come, have been particularly inspiring. I do not think anyone could have listened to our President without feeling that behind those quietly spoken words there was a wealth of experience and a power which went out to each one of us. The gist, if I read it aright, was that what one man has done many of us can at least attempt to do, and by the attempting thereof this, our own and beloved country, would be very much better. This I took to be the sense behind Lord Nuffield's words. The key struck has been all that we could desire, and inadequate though my words are, nevertheless the feeling behind them is given with all the sincerity of which I am capable.

The Rt. Hon. LORD SEMPILL, A.F.C. (Immediate Past-President) in proposing the toast of "The President," said: I am sure that you will enthusiastically agree with me that never in the history of Institutions, for whatever purpose they may exist, has an Immediate Past-President been faced with a more difficult task than that which presents itself to me at this moment. I am deeply conscious of the high honour that rests upon my unworthy shoulders and see

before me the shadows of those behind ready and anxious to step into the breach. But no Scotsman could be persuaded to give way, and so I stand firm and hope that some of the erudition and capacity to express the highest thoughts in beautiful and ever to be remembered language of the late Attorney-General, now the Minister for the Co-ordination of Defence, will transmit itself in part to me, amplified, I hope, by my Lord Austin, one of the robust and dynamic controlling figures of the Shadow Industry that aims to deliver thousands of aircraft and engines to propitiate that Oliver-Twist-like personality, Colonel Disney, the Director of Aircraft Production.

What can I say about my Lord President that the Empire, nay the world, does not know ? This does not matter, as from his ascent from the foot of the ladder, through the Stratosphere to the Stars, we can learn much, and the story of a life so full of usefulness can never be told too often.

Many years ago Lord Nuffield decided to work for W. R. Morris, as he thought he would pay him more than anyone else. In that year he built and sold 50 bicycles. In recent years he has entirely given up the original idea of working for himself and now works for others in a variety of ways that the pages of national, technical, and industrial history reflect. " Between the boy who said one thing and did it, and the man who said another and does it, there lies forty-three years of hard work—and a motor-car." Our President has played a part in all fields of modern road transport development —bicycles, motor-cycles, and cars, and, in fact, we must liken him to a modern Atlas carrying a very large portion of the Empire on his shoulders. We all know the feeling and some of you may have been lucky enough, like myself, to fly behind a Morris aero-engine so you can see that our Atlas grows wings.

It would be impossible to give details of all that our President has done for the national welfare and the development of road transport, but I will give you a few graphic illustrations. In 1921 the country suffered a severe depression —gloom was universal—prices sky-rocketed—some talked of closing works. Lord Nuffield cut all prices by £100 on the eve of the Motor Show and drove forward to that success that comes to those who lead boldly when all looks dark.

London, the heart of the Empire, is not an ideal parking place, but if we wish to visualise his products at one time it would need an area of seven and a half times that of the City of London to park all the motor vehicles manufactured by Lord Nuffield's various companies. It is a far cry from London to New York and the splendid trans-atlantic flying boats of Imperial Airways cannot fly there non-stop, but all Morris vehicles if put together would just span this distance, or if you prefer it, build, by placing cars one on top of another, 232 columns as high as Mount Everest—Lord Clydesdale, please note.

All Scotsmen are intrigued by the idea of something free, and Lord Nuffield has used more than his share of our atmosphere to pump up the tyres of the vehicles he has produced, which would fill the Graf Zeppelin four times, and still have enough over for a season's flying.

The examples I have just given you illustrate in a graphic fashion the magnitude of our President's contributions to the field of road transport, but formidable though they are, not even a half has been said about him, as his real record-breaking achievements have hardly been touched upon. His astronomical and golden benefactions, appreciated no doubt to the full by Sir James Jeans, must, for our purposes, come off the gold standard and appear in the more sombre copper we know well enough. You will remember that with the motor vehicles Lord Nuffield built 232 columns as high as Mount Everest, now with the pennies he has in his magnificent munificence distributed in so many worthy causes, laid one on top of the other he could build 681 columns, or laid side by side span the Atlantic 19 times or encircle the earth 2¼ times at the Equator.

All of us have—I mean all those in the Empire—benefited by the great example he has set us and those who follow after us will benefit to a greater extent. The immense value of the far-sighted support he has given to important National Institutions is appreciated, but its full significance and effect has yet to be felt. I realise how inadequate my words are and I am sure that the warmth of the reception you have had to-night, and will ever receive from all members of this Institution, will show you how proud we all are to have you as our President. Lead and we will follow and attempt, according to our lights, to emulate your example of service to others.

I have tried to find words in which to express our admiration of the great work you have done during forty years of uninterrupted effort devoted primarily to the good of others. I openly confess that the task is too great and I have looked back in history to find what the greatest historians have said about those who have made their mark in this land. I think you will agree that I have chosen well. Nearly 2,000 years ago Agricola was Governor of Britain. He was a great soldier and administrator and displayed conspicuous success in quelling most of our warring forebears—except the Highlanders—and planted the first seeds of nation-wide education. Tacitus, the son-in-law of Agricola, one of the greatest of the Roman historians, wrote his father-in-law's life, and closes the last chapter with these words :—

> "Whatever we have loved in Agricola, whatever we have admired, remains and will remain in the minds of men for ever and ever embedded in the very record of things."

My Lord President, these great words explain our deepest feelings and apply to you in full measure. It is an honour as your Immediate

Past-President to propose this toast, and I know that all Past-Presidents will join with me in calling on you to drink my Lord President's health with enthusiasm.

The toast was honoured with enthusiasm and duly acknowledged by the President.

During the evening a musical programme, under the direction of Mr. Victor Marmont, was given by the following artistes: Mr. Thorpe Bates, *Baritone*; Mr. Stock Wynn, *Entertainer*; The Concord Singers, *Vocal Quartette*; Mr. Victor Marmont, *at the Piano*.

PRACTICAL RESEARCH IN PRODUCTION ENGINEERING.

Paper presented to the Institution, London, Manchester, and Birmingham Sections, by Dr. Georg Schlesinger.

PRACTICAL research in production engineering means that the results of scientific tests are transformed into direct practical application. The exploitation of the workshop is in the hands of the ratefixing department and the ratefixer must have a clear survey of: (1) methods of machining raw material; (2) kind of tool; (3) available machine tools and admissible speed and feed. Of these elements, raw materials and tools are always changing. Raw materials are growing more resistant, tools are developed to higher cutting speeds. The machine tools follow very slowly and are, with most of the users, not changed for years.

We may divide the workshop of to-day into three different classes :—

(1) Those equipped with machine tools from 1900 to 1930, with more or less obsolete machines which still turn, drill, mill, and grind ; (2) those from 1906 to 1935, with old and fairly new machines; (3) those from 1935 to 1937, with very useful and also most modern machines.

Factories established after 1930 are very rare, both on the continent and in Great Britain. The only exceptions I know are some factories in Russia, which had a chance to provide a most modern equipment throughout.

As the real introduction of cemented tungsten-carbide tools for general use on all raw materials did not take place before the last four years, 1933 to 1937, the majority of the existing workshops belong to the classes 1 and 2, and it is not possible either to replace all the not quite modern machine tools or to recondition them to the cemented carbide speeds.

Research must create ideal working conditions, in using the best tools and very uniform raw materials. The machine tools of a research institute must be designed specially for testing purposes, very strong and rigid, with an unusually wide range of speeds and feeds equipped with measuring instruments to measure the cutting forces directly at the cutting edges and to compare the mechanical final effect of the tool with the electrical in-put to the motor. Further, it must be easy to calibrate the measuring gauges in due time. The scientific results of the tests must then be transformed

at once into practical prescriptions for the user,—that is, the production engineer.

My report of research is based on the experience of long years in investigating raw materials for the automobile industry, the steel makers and makers of alloyed steels of different kinds. Further, by investigating white metals, especially electron for the I.-G.-colours. We had to find :—

(1) The best angles for the lathes and planer cutting tools.

(2) The best shape for the twist drills in machining deep holes.

(3) The best form of the milling cutters for steels.

(4) Selecting the most effective grinding wheel.

(5) The influence of cutting coolants.

It has been fortunate that the applicability of the data could be again proved in the last two years, from 1935 to 1937, in three different continental shops whose equipment was in some cases very old. It was the task either to recondition the adaptable machines or to replace the non-adaptable by new ones, regard being had to the eternally difficult question—When is a machine old ?

These three were :—

(1) A machine tool factory of 280 men making high quality tools of medium size in small quantities, five to 10 machines.

(2) A dock-yard of 4,000 wage earners, the central machine shop of which had 500 men ; they made one, two, up to five new engines, steam, gas, diesel engines, steam turbines, and all classes of heavy armament for warships, and they repaired all sorts of merchantmen ; 40% of the work was new, 60% repair work.

(3) A factory of 1,200 workmen for heavy new engines, gas, steam, single diesel engines, locomotives up to 20, cranes and complete ships.

You will, I hope, be able to judge whether the results of research and their practical application can be transferred to your own conditions. We won't talk paper but create life. Men, means, opinions, experience, psychology, and sociology change from one place to another. Varying conditions cause different solutions, even by applying the same scientific study to another shop. It is the interesting task of the production engineer to find the most economical and practical solution for a given case.

He who intends to reorganise and improve the productive effect of any shop, either by raising its output or by decreasing its expenses, must study thoroughly the " Law of Life " of the factory. This task is solved by the collaboration of ratefixing office, foremen and workmen. The ratefixer writes the prescription, the foremen teaches the workman, and the latter tries whether raw material and tool allow him to follow the plan or force him to decrease the speed. The table (Fig. 1) accommodates itself to these

		Tools	Speed m/min	Feed mm/rev	Steels: C-Ni-NiCr				Steel-Castings		Cast Iron		Bronze		Brass		Light Metals	
					to/sq.i 22-32	to/s.i 34-44	to/s.i 45-55	Stainless 32-42	soft 22-32	hard 34-45	soft <180B	hard >220B	soft	hard	soft	hard	soft	hard
Turning	Roughing	High Speed	v	s	45 / 1-10	35 / 1-6	30 / 1-2	25 / 0,6-1,5	35 / 0,3-3,5	25 / 0,3-3	30 / 1-2	25 / 1-2	80 / 0,8-2,5	40 / 0,6-1,5	100 / 0,4-3	60 / 0,3-2	250 / 0,4-3	200 / 0,3-2
		Supra Cobalt	v	s	60 / 0,5-6	50 / 0,5-3	40 / 0,5-2	30 / 0,5-2	50 / 0,5-2	35 / 0,5-2	40 / 1-2	28 / 1-2	100 / 0,6-2,0	60 / 0,5-1,5	150 / 0,3-2,5	100 / 0,3-1,5	500 / 0,3-2	400 / 0,3-1,6
		Tungst. Carb.	v	s	100 / 0,3-2	85 / 0,3-2	70 / 0,3-1,5	50 / 0,3-1,5	70 / 1	45 / 1	75 / 1-2	50 / 1-2	200 / 1	100 / 1	300 / 1	200 / 1	1000 / 1	800 / 1
	Finishing	H S	v	s	60 / 0,2-0,3	50 / 0,2-0,3	40 / 0,2-0,3	32 / 0,2-0,3	45 / 0,2	35 / 0,2	40 / 0,2-0,3	30 / 0,2-0,3	100 / 0,2-0,3	60 / 0,2-0,3	150 / 0,2	80 / 0,2	300 / 0,1-0,2	250 / 0,1-0,2
		S Co	v	s	75 / 0,2-0,3	60 / 0,2-0,3	50 / 0,2-0,3	40 / 0,2-0,3	60 / 0,2	45 / 0,2	50 / 0,2-0,3	35 / 0,2-0,3	150 / 0,2-0,3	90 / 0,2-0,3	200 / 0,2	150 / 0,2	600 / 0,1-0,2	500 / 0,1-0,2
		T Ca	v	s	180 / 0,2-0,3	130 / 0,2-0,3	120 / 0,2-0,3	80 / 0,2-0,3	100 / 0,2	60 / 0,2	80 / 0,2	60 / 0,2	300 / 0,2	150 / 0,2	400 / 0,2	300 / 0,2	1200 / 0,1-0,2	1000 / 0,1-0,2
	Threading	H S	v		12	10	8	6	8	6	8	6	15	6	25	12	35	15
		S Co	v		18	14	12	10	10	6	12	9	20	10	40	15	50	25
		–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–
Planing		H S	v	s	30 / 1-10	24 / 1-6	16 / 1-3	10 / 0,8-1,5	16 / 0,8-3	12 / 0,8-2	24 / 0,5-12	16 / 0,5-12	24 / 0,5-6	16 / 0,5-6	40 / 0,2-4	30	50 / 0,2-4	40
		S Co	v	s	40 / 1-10	32 / 1-6	22 / 1-3	14 / 0,8-1,5	24 / 0,8-3	16	30 / 0,5-12	24	30 / 0,5-6	24	60 / 0,2-4	45	80 / 0,2-4	60
		–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–
Boring	Twist Drill	H S	v	s	15	20 / s = 0,1d	18	15	20 / s = 0,1d	15	16 / s = 0,1d		16 / s = 0,15d		200 / 0,05d	50 / 0,1d	300 / 0,1d	200
		S Co	v	s	40	30 / s = 0,1d	25	20	30 / s = 0,1d	20	20 / s = 0,2d		24 / s = 0,15d		–	–	–	–
		–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Boring Bar	H S	v	s	30 / 0,2-1	25 / 0,2-1	20 / 0,2-0,8	15 / 0,2-0,8	10 / 3-0,2	8	15 / 5-0,2	10	40 / 0,2-0,8	20	70 / 0,2-1,0	30	250 / 0,1-1,0	150
		S Co	v	s	40 / 0,2-1	32 / 0,2-1	28 / 0,2-0,8	20 / 0,2-0,8	20 / 3-0,2	14	25 / 5-0,2	18	60 / 0,2-0,8	30	100 / 0,2-1,0	50	400 / 0,1-1,0	300
		T Ca	v	s	60 / 0,2-1	50 / 0,2-1	40 / 0,2-0,8	30 / 0,2-0,8	40 / 2-0,2	25	60 / 4-0,2	30	80 / 0,2-0,8	40	150 / 0,2-1,0	80	600 / 0,1-0,8	400
	Reamer	H S	v	s	18 / bis 3	14 / bis 5	12 / bis 2	10 / bis 2	12 / bis 3 mm	8	12 / bis 5 mm	12	12 / bis 5 mm	8	28 / bis 10 mm	22	40 / bis 10 mm	30
		S Co	v	s	"	"	"	"	"	"	"	"	"	"	"	"	"	"
					–	–	–	–	–	–	–	–	–	–	–	–	–	–

Fig. 1.—Table of Cutting Speeds and Feeds in relation to raw materials.

different demands of the shop. What makes it difficult to set up such a table is that in turning, planing, drilling, milling, and grinding the cutting speed changes in consequence of the manner of cutting. Another complication arises from the fact that roughing must be done much slower than finishing and that, with certain ways of manufacturing, the speed diminishes still more, e.g., in cutting threads and in reaming.

Every machine shop has a list containing the raw materials which are used in the drawing office by the designers. This list contains all kinds of steels, beginning with mild steel for screws and other subordinate purposes up to the hardest alloyed steels for gears and main spindles and other hard stressed parts, and, further, the very tough stainless steels in shipbuilding. We must add the cast materials, soft and hard steel castings, grey iron castings, bronze, brass, aluminium, and other light alloys. The automobile and diesel ship's machine construction have an enormous choice of materials, at least 12 to 20 kinds, which the production engineer must manage.

Further, the speed is of special importance. The cutting force F is the result of feed $\times$ depth $\times$ specific stress and thus the power of the motor $N = F.V.K.$ is directly dependent on the force and the speed, i.e., again raw material and tool. All modern machine shops now use high speed tools but, as old machine tools exist, the quality of these machines determines the kind of tool to be selected. Three kinds of tool steels may be used as standards in the ordinary workshops :—

(1) Common high speed steel for older machines and roughing on newer machines.

(2) Cobalt high speed steel for about double the speed in finishing and for use on machine tools of about five to ten years of age.

(3) Tungsten Carbide (Wimet, Widia, Ardoloy, Carboloy etc.) for the machine tools from 1935 onwards with high speeds and strong motors. On this basis is the table Fig. 1, which can be used by the ratefixing office, so that the ratefixer is able to utilise with a good knowledge of shop capabilities the entire range of machines of a factory which will generally be composed of older, old and new machines.

How is such a table obtained? How is it possible to keep it constantly up to date? That is to say, how can one adapt it permanently to the incessant development in the improvement of the raw materials, of the tools and the machine tools? First of all, there must be fixed in the storeroom which distributes the raw material the tensile strength of the bar or of the forging to fix the method of its machinability. In most cases the testing of the newly arriving materials with the Brinell press is found sufficient. This gives first of all the Brinell hardness (H) and a table with

figures gives the Brinell tensile strength (R). There is pretty good relation between Brinell hardness and machinability of steels. Many shops are accustomed to regard the tensile strength as a basis for the machinability and use it for the cutting speed.

NORMENSTÄHLE

a) Legierte Normenstähle nach DIN 1662

	Markenbezeichnung nach DIN 1662	geglüht: Brinellhärte H höchstens	geglüht: Brinellfestigkeit kg/mm² höchstens	gehärtet bezw. vergütet: Zugfestigkeit kg/mm²	gehärtet bezw. vergütet: Streckgrenze in % der Zugfestigkeit mindestens	gehärtet bezw. vergütet: Bruchdehnung in % $l=10\,d$	Chemische Zusammensetzung in %: Kohlenstoff C	Nickel Ni	Chrom Cr	Mangan Mn	Silizium Si höchstens
1	EN 15	162	55	60–80 Wasser	65	15–8	0,10–0,17	1,5±0,25	höchstens 0,2	höchstens 0,5	0,25
2	ECN 25	206	70	80–100 Öl 90–110 Wasser	70 Öl 75 Wasser	14–10 Öl 12–7 Wasser	0,10–0,17	2,5±0,25	0,75±0,2	höchstens 0,5	0,35
3	ECN 35	220	75	90–120 Öl	75	12–6	0,10–0,17	3,5±0,25	0,75±0,2	höchstens 0,5	0,35
4	ECN 45	240	83	120–140 Öl	75	10–5	0,10–0,17	4,5±0,25	1,1 ±0,2	höchstens 0,5	0,35
5	VCN 15 w	206	70	65–75	65	16–13	0,25–0,32	1,5±0,25	0,5 ±0,2	0,4–0,8	0,35
6	VCN 15 h	206	70	75–85	70	15–12	0,32–0,40	1,5±0,25	0,5 ±0,2	0,4–0,8	0,35
7	VCN 25 w	220	75	70–85	70	14–10	0,25–0,32	2,5±0,25	0,75±0,2	0,4–0,8	0,35
8	VCN 25 h	220	75	80–95	70	12–8	0,32–0,40	2,5±0,25	0,75±0,2	0,4–0,8	0,35
9	VCN 35 w	235	80	75–90	75	14–10	0,20–0,27	3,5±0,25	0,75±0,2	0,4–0,8	0,35
10	VCN 35 h	235	80	90–105	75	12–8	0,27–0,35	3,5±0,25	0,75±0,2	0,4–0,8	0,35
11	VCN 45	265	90	100–115*	80	10–6	0,30–0,40	4,5±0,25	1,3 ±0,2	0,4–0,8	0,35

Gegenüberstellung der Marathon-Marken- und Normenbezeichnungen nach DIN 1662

Einsatzstähle:

	Bezeichnung nach DIN 1662	Bezeichnung nach SAE	Markenbezeichnung: Marke	Markenbezeichnung: BSI-Bezeichnung
	St. C. 10. 61 (nach DIN 1661)	1010	EW	EW
	St. C. 16. 61 (nach DIN 1661)	1015		
	EN 15	2115	NW 2	NW 2
	–	2315	NW 3	NW 3
	-	2512	NW 5	NW 5
	–	4615	MOW	ZM 15
	-	6115	CVW	CVW
2	ECN 25	–	CNW 3	E 53
3	ECN 35	–	CNW 4	E 734
4	ECN 45	–	CNWZ	LWZ

Vergütungsstähle: (einschl. Luft- und Ölhärtestähle)

	Bezeichnung nach DIN 1662	Bezeichnung nach SAE	Markenbezeichnung: Marke	Markenbezeichnung: BSI-Bezeichnung
	–	2330	DN 3	DN 3
5	VCN 15w	3130	DN 2	HBN
6	VCN 15h	3135		
	–	3145	DN 2h	–
7	VCN 25w	–	DCN 2w	V 53
8	VCN 25h	–	DCN 2	–
9	VCN 35w	–	DCN 3w	V 734
10	VCN 35h	–	DCN 3	KWD
11	VCN 45	–	DCN 4	LWD
		–	DCNA	DCNA
	–	4130	DMOC	BSF
	–	4150	DCR	ZO
	–	6130	CVH	–
	–	6150	DCRV	ZO,V

Fig. 2.—German and American standards of alloyed steels.

In the shops with scientific management one often finds at the machine tool a table which gives the kind of material with the corresponding cutting speed and feed and above it a graph which

allows one to find, from chip section and cutting speed, the number of revolutions of the spindle which the workman has then to set up in order to reach the cutting time on the wage sheet and to make a satisfactory bonus. But it must not be forgotten that the execution of work never is the same as the mathematical problem. The sharpness of the tools and the quality of the raw material change incessantly, even if they are supposed to have always the

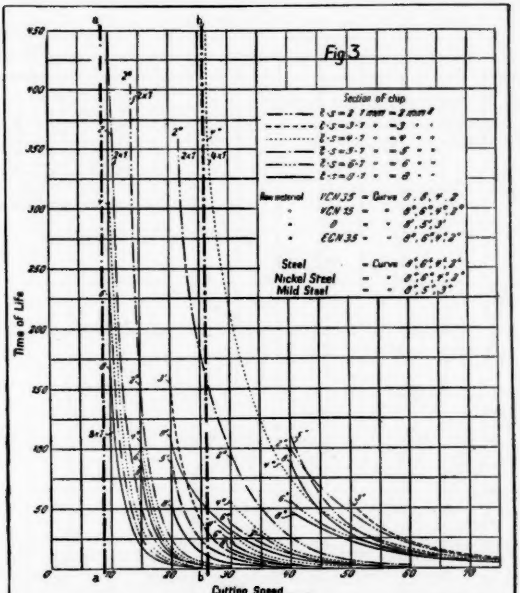
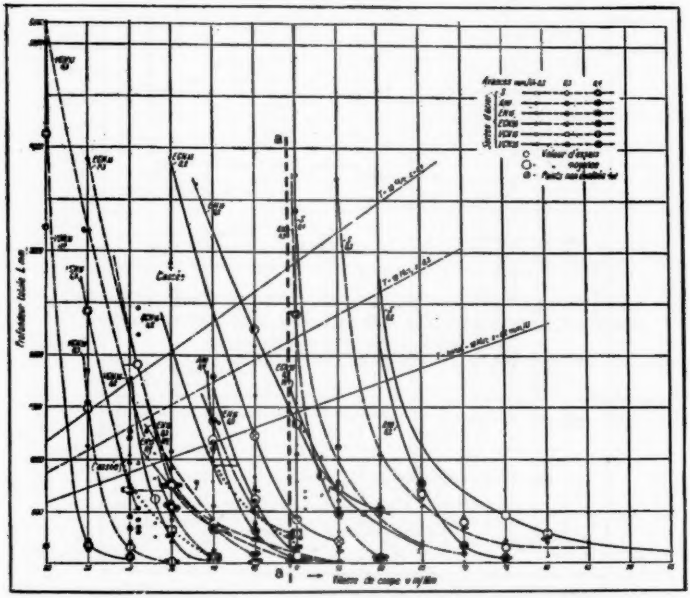


Diagram of chrome nickle steels and ordinary steels of 40-45 (mild) and 60-65 (middle-hard), aa, bb, are tangents to the hyperbola.

same components and to be from the same manufacturer. Therefore we must look for a practical basis to facilitate the fulfilment of the ideal condition. This will be the easier, the more we succeed in standardising the composition of the raw materials and the cutting angles of the tools. Well known are the standards of the American S. A. E. (Society of Automotive Engineers) and the German RDA (Reichsverband der deutschen Automobilindustrie DIN 1662).

The RDA table Fig. 2—DIN 1662 selects from 42 different special steel alloys which exist and about 11 high grade steels, which meet very largely the demands of general use. On account of the smaller number of steels, it was possible to fix a programme for tests in order to find the best cutting angles and the corresponding speeds for cutting in using a standard tool made of Tungsten high-speed steel as it was in common use about eight to ten years ago. This tool of standard high-speed steel was our gauge tool. The cutting was done with a very constant kind of tool steel and with not too



Courbes de durée pour le perçage a, a = tangente caractéristique pour l'acier A 90-0,3

Fig. 4.—TV graphs of twist-drills.

long a series of test—only three years' work. They represent the so-called Tv curves (Figs. 3 and 4) which allow of reading the cutting speeds v in m/min. and the cutting time T in minutes, until the edge is blunted by the mostly used kinds of steel with different sections of chip. The tangents at the curves give the admissible cutting speed which the ratefixing office on the one hand and the workman on the other hand have to use in order to work one day 400 minutes with a sharp tool.

If better tools come on the market it will be easy to state the increase of speed by the new tool in comparison to the gauge tool, without repeating all the tests which lasted long years and used a lot of material. A graph (Fig. 5) shows, in comparing the curves of life, the increase of the capacity of the super Cobalt steel and the Tungsten Carbide with that of the old 18% Tungsten Carbides. It would suffice to send the new tool to a central Research Institute to fix in a proportionately short time the index number of the new tool or of a new kind of material in comparison with the gauge tool and gauge material. This would give at once the new data for the rate-fixing office.

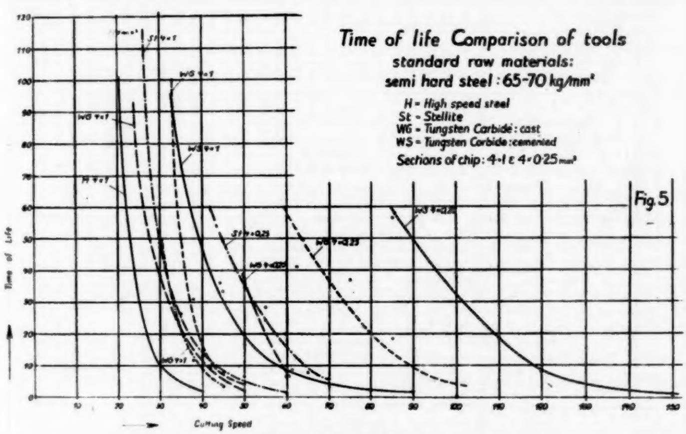


Fig. 5.—Comparison of tools, high speed steel, etc.

Cutting speed, section of chip, and life of tool are the three fundamentals, the development of which must be followed by the production engineers of all interested industries, as :—

(1) The steel works as furnisher of raw materials and tool steels.

(2) The machine tool manufacturer as furnisher of machines being more rigid and working quicker.

(3) The user of both.

By constant information concerning the new development, all the metal-working industries would be enabled to make the right decision, either to accommodate themselves to the new development or, if the special basis of economy and success in the works does not allow it, to retain the present installation for a certain time until it is obsolete. The very serious question " When is a machine old ? " may be easier answered if the above-mentioned information flows

πD	Diam of piece	6.2	8	10	12.5	15.8	20	25	31.5	40	50	61.5	80	100	126	160	200	250	315	400	500	615	800	1000
		number of revolutions = n																						
31.4	10	0,2	0.25	0.3	0.39	0.5	0.6	0.8	1	1.3	1.6	1.9	2.5	3.1	4	5	6.3	7.8	10	13	16	19	25	31
47.1	15	0,3	0.38	0.5	0.59	0.7	0.9	1.2	1.5	1.7	2.4	2.9	3.8	4.7	6	7.5	9.4	11.7	15	17	24	29	38	47
62.8	20	0,4	0.5	0.6	0.78	1	1.2	1.6	2	2.5	3.2	3.9	5	6.3	8	10	12.2	15.7	20	25	32	39	50	63
78.5	25	0,5	0.6	0.8	0.98	1.2	1.6	1.9	2.5	3.1	3.9	4.8	6.2	7.9	10	12.5	16	19	25	31	39	48	62	79
94.2	30	0,6	0.75	0.9	1.2	1.5	1.9	2.3	3	3.8	4.7	5.2	7.5	9.4	12	15	19	23	30	38	47	52	75	94
109.9	35	0,7	0.87	1.1	1.4	1.7	2.2	2.8	3.5	4.4	5.5	6.8	8.7	10.9	14	17.5	22	28	35	44	55	68	87	109
125.7	40	0,8	1	1.3	1.5	2	2.5	3.2	4	5	6.3	7.7	10	126	16	20	25	32	40	50	63	77	100	126
141.4	45	0.9	1.1	1.4	1.7	2.2	2.8	3.5	4.5	5.6	7.1	8.7	11	141	18	22.5	28	35	45	56	71	87	110	141
157.1	50	1	1.3	1.6	1.9	2.5	3.2	3.9	5	6.3	7.8	9.8	12.5	15.7	20	25	32	39	50	63	78	98	125	157
172.8	55	1.1	1.4	1.7	2.1	2.7	3.5	4.3	5.5	7	8.6	10.6	14	17.5	22	27.5	35	43	55	70	86	106	140	173
188.5	60	1.2	1.5	1.9	2.3	3	3.8	4.7	6	7.5	9.4	11.6	15	189	24	30	38	47	60	75	94	116	150	189
210.9	70	1.4	1.7	2.2	2.7	3.5	4.4	5.5	7	8.8	10	13.5	17	22	28	35	44	55	70	88	100	135	170	220
251.3	80	1.6	2	2.5	3.1	4	5	6.3	8	10	12.5	15.5	20	25.1	32	40	50	63	80	100	125	155	200	251
282.7	90	1.8	2.3	2.8	3.5	4.4	5.6	7	9	11.3	14	17.5	22.6	283	36	45	56	70	90	113	140	175	225	282
314.2	100	2	2.5	3.1	3.9	5	6.3	8	10	12.5	15.7	19.5	25	314	40	50	63	79	100	125	157	196	250	314
345.6	110	2.2	2.8	3.5	4.3	5.5	6.9	8.8	11	13.8	17.2	21	27.5	346	44	55	69	87	110	138	172	210	275	345
377	120	2.4	3	3.8	4.7	6	7.6	9.5	12	15	18.5	23	30	377	48	60	76	95	120	150	185	230	300	377
408.4	130	2.6	3.3	4.1	5.1	6.4	8.1	10	13	16	20	25	32.5	408	52	65	82	102	130	160	200	250	325	408
439.8	140	2.8	3.5	4.4	5.5	6.8	8.8	11	14	17.5	22	27	35	44	56	70	88	110	140	175	220	270	350	440
471.2	150	3	3.8	4.7	5.9	7.4	9.4	11.8	15	19	23.5	29	38	47.1	60	75	94	118	150	190	235	290	380	471
549.8	175	3.5	4.4	5.5	6.8	8.6	11	13.7	17	22	27.5	34	44	55	70	87	110	137	170	220	275	340	440	550
628.3	200	4	5	6.3	7.8	10	12.6	15.6	20	25	31.5	39	50	628	80	100	125	156	200	250	315	390	500	628
785.4	250	5	6.3	7.9	9.8	12.4	15.6	19.5	25	31.5	39	48	63	785	100	125	156	195	250	315	390	480	630	785
942.5	300	6	7.5	9.4	11.8	14.8	18.8	23.4	30	37.5	41	58	75	943	119	150	188	235	300	375	410	580	750	943
1099.6	350	7	8.8	11	13.5	17.2	22	27.6	35	44	55	68	88	110	139	175	218	276	350	440	550	680	880	1100
1256.6	400	8	10	12.5	15.5	20	25	31.4	40	50	63	78	100	1257	158	200	250	314	400	500	630	780	1000	1256
1413.7	450	9	11.4	14.1	18	22.5	28	35.5	45	57	70	88	113	1414	178	225	280	355	450	570	700	880	1130	1414
1570.8	500	10	12.5	15.7	20	24.7	31	39	50	63	78	97	125	157	198	250	314	390	500	630	780	970	1250	1570
1727.9	550	11	14	17.5	21.5	27.3	35	43	55	70	87	107	137	1128	220	275	346	430	550	700	870	1070	1370	1728
1885	600	12	15	18.9	23.5	30	38	47	59	75	94	116	150	1885	240	300	378	470	590	750	940	1160	1500	1885
2042	650	13	16.3	20.4	25.5	32	41	51	64	82	102	125	162	2042	260	325	408	510	640	820	1020	1250	1620	2042
2199	700	14	17.5	22	27	34.5	44	55	69	88	109	135	175	220	278	350	440	550	690	880	1090	1350	1750	2200
2356	750	15	18.6	23.6	29.5	37	47	58.5	74	94	118	145	188	2356	293	375	472	585	740	940	1180	1450	1880	2356
2513	800	16	20	25.1	31.5	40	50	63	79	100	125	155	200	251	316	400	500	630	790	1000	1250	1550	2000	2513
2670	850	17	21.5	26.7	33	42	54	67	84	107	132	165	212	267	335	425	532	670	840	1070	1320	1650	2120	2670
2827	900	18	23	28.3	35.5	45	57	71	90	113	141	175	225	283	356	450	564	710	890	1130	1410	1750	2250	2827
		CUTTING SPEED : v = π·d·n (m/sec)																						

	High Speed Steel	Tungsten Carbide
Threading		
cutting at present		
in future		

Range

old	adapted	modern	ratio
6.5:200	5:450		1:30
11:330	22:660	23.5:750	~1:30
		23.5:1050	1:45
		47.5:2100	1:45
		33.5:3000	1:90

$$V = \pi d n \ (m/sec)$$

$$N = a \cdot F \cdot v \ (HP)$$

Fig. 6.—Relation of revolution, speed and diameter, high speed steel and tungsten carbide.

regularly from a Research Institute. To investigate raw material and tools a permanent installation is generally sufficient, if it covers a wide range of fast speeds and great forces for the supposed development of the next ten years.

The equipment of the Charlottenburg Research Institute was useful from 1906 to 1933 for my own investigations, but it now requires modernising. From the Taylor-White tool steel with 8% tungsten to the Super Cobalt with 18% tungsten and 10 Cobalt and for Stellite the machines proved very satisfactory.

There is no doubt that in fixing the cutting speed and the section of chip the preparation of the rough pieces as far as they are delivered by the forge and the foundry is of greatest importance, as the section of chip depends on the allowances. The more accurate the forging and the castings, the smaller the allowance, for then the chip, and with it the forces, get smaller and the cutting speed may be increased. These results can lead to full profit of the existing motor without any change in using the new tools.

This adaptation is impossible with parts of steel turned from the full bar. The allowance depends in this case upon the design and not upon the castings and forgings. For keeping up progressive production it will be necessary to make a scheme as the basis for the ratefixing office. It will contain in the vertical direction all diameters from the smallest up to the largest, on the top in horizontal line will be given all the numbers of revolutions which might be the speeds for all machine tools of one group, e.g., all lathes of the shop. The whole inner field gives the speeds which are based mathematically on the supposed numbers of revolutions and the required diameters by the formula $V=dn$. (Fig. 6).

The ratefixer must know the number of revolutions existing for all machine tools, which requires a large card-index. The drawing will give the required diameter, the correct cutting speed for material, section of chip for the corresponding machine tool, all combined on the table if the kind of cutting tool is fixed. The wage sheet of the workman will contain the material and the selected cutting speed. A somewhat similar table is hanging at the machine of the workman, the vertical data is just the same as on that of the ratefixer, but the horizontal line on top contains the actual series of revolutions of the machine tool in question. As the workman knows the diameter of the workpiece from the drawing, and the cutting speed from the wage sheet, he finds by merely glancing at the table the number of revolutions nearest to the cutting speed prescribed for the piece. He has been told to take always the number of revolutions coming next above so as to be sure to reach the bonus lying in the contract. This may be done without any danger as the new rapid tools of to-day will allow a higher number of revolutions than the rate-

fixer will give considering the present size of the motor driving the machine.

It is not possible to follow immediately every new invention which may increase production in the shop. The Taylor-White steel was shown for the first time in 1900 at the World's Exhibition at Paris. Its influence on the design of the machine tool has caused a revolution, the cone pulleys having to yield to the geared drive, the keyed shaft to the spline shaft, the cast gears to hardened and ground steel gears. It was more than twenty-five years before the machine tool builders could follow the great improvements of the tools. In 1910 the Cobalt steel came on the market, in 1929 the

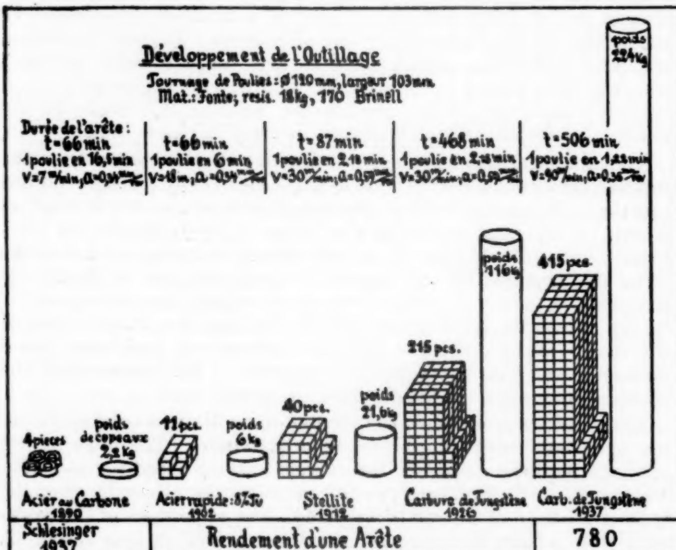


Fig. 7.—Development of tools, efficiency.

cemented Tungsten Carbide tools, with another enormous increase in the capacity of the tools. The influence on the design of the machine tools is in progress but is in no way finished, and although a great number of designs are on the market which allow one to profit by the increase of speed of the Tungsten Carbides, the general shop management is not able to buy all new machines to meet the constant superiority of the tools and to profit by it. The shop administration should try to accommodate their work as much as possible to the changed conditions of cutting speeds, and we have

to show the way for these improvements which the shop in evolution can undergo without having too great expenses. Fig. 7 shows the enormous increase in output through the development of tools from 1890 to 1937.

First of all, propositions have to be worked out for a suitable standardisation of the numbers of revolutions. If all the machine tools of the shop had equal numbers of revolutions for one group of machines, the ratefixing office would have easy work. The time study would not only give the best cutting speed, but also the number of revolutions always attainable at the machine tool. That is nowadays quite impossible, e.g., each lathe manufacturer has with different sizes of his lathe programme, not only the necessary change of speed but quite different numbers within the series of revolutions. Some designers change almost every three years their numbers for the same type. If an automobile shop buys but a few types of each good lathe, one can imagine how many series of numbers there are in only one single automobile shop. The ratefixing becomes difficult, the workman and foreman laugh at the time study, the best cutting speed varies from 6 to 12%, depending on the lathe, which must be used, as no other is free. This touches one of the most important questions of the machine tool industry. The accomplishment of the standardisation of the numbers of revolutions demands from the designer of machine tools a certain restriction in the choice of the ratios of his gears. Consequently the number of the teeth and the distance of shafts is fixed and it may be difficult for the designer to comply with this demand. On the other hand, this standardisation will be of very great help to all users of machine tools who would profit to a great degree in the machine shop. The ratefixing office would have for one group at least the same series of revolutions, which would lead to the possibility to profit fully by the time studies with all their known good consequences. The revolution which was produced by the Super Cobalt Tools and the Tungsten Carbide Tools must be utilised fully.

How would the old machine tools be adapted to the new methods ?

(1) We want a certain type of shape of tools : (*a*) For the personal use of the single worker ; (*b*) for the common use of all workers. The tools for (*a*) must always be on the worker's machine. The tools for (*b*) are proportionally less used. It will therefore suffice if they are in the distribution of the tool room and may quickly be obtained by all workmen at any time with the help of a suitable organisation.

(2) The type of the machine tool gives the section of the tool shank.

(3) The kind of material to be machined gives the cutting speed and the feed. (Compare Fig. 1).

The demands for the personal and general use give the total number of tools.

Attention must be given to the fact that the kind of material both for the tool and for the work-piece demand different kinds of cutting angles, and these cutting angles can only be found by research (Fig. 8). The right cutting angles giving the least forces

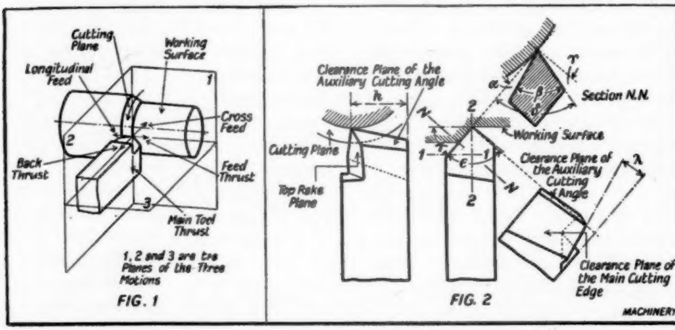


FIG. 1 FIG. 2

TABLE 1A. TOOL ANGLES FOR VARIOUS MATERIALS			
Clearance Angle α deg.	Wedge Angle β deg.	Top Rake Angle γ deg.	Class of Material to be Machined
6	84	0	Chilled Iron and Very Brittle Brass and Bronze
8	74	8	Steel and Cast Steel of more than 45 tons per sq. inch Tensile Strength. Hard Cast Iron with Brinell Hardness Hn of more than 115 tons per sq. inch, Cast Brass; Bronze and Yellow Brass
8	68	14	Steel and Cast Steel of 32 to 45 tons per sq. inch Tensile Strength. Cast Iron of Brinell Hardness Hn of less than 115 tons per sq. inch. Soft Yellow Brass.
8	62	20	Steel and Cast Steel of 22 to 32 tons per sq. inch Tensile Strength
8	55	27	Tough and Soft Bronze. Very Soft Steel
10	40	40	All Soft Metals Pur Aluminum

Fig. 8.—Relation between raw material and cutting angles.

in cutting and so the best exploitation of the machine. The chip remains white instead of growing blue or red, and unnecessary production of heat is avoided.

The tools do not get so quickly blunt, it is not necessary to sharpen them so often, the expenses for the upkeep get less and it is possible to centralise the sharpening of the tools. The workman does not spoil the tool by ignorance, we have exact angles, long lasting tools, increase of production, decrease of cost, and greater profits.

The table of figures (Fig. 9) shows how to proceed first of all to get reasonable primary costs for new installations. If they are too high, the ordinary proprietor with small means will not be able to buy the finest installation. Then the result of a scientific research is of great value, to show the way which even the smallest shop

		TOOLS FOR LATHES										20 MACH.		
			NUMBER OF TOOLS: SERVICE and STOCK											
		SECTION OF SHANK	ROUGHING	FINISH	RAP. SPEED	ROUGHING	FINISH	RAP. SPEED	ROUGHING	FINISH	RAP. SPEED	TOTAL		
TOOL	SHAPE		STEEL OF [illegible]			STEEL OF 35/45 T.Y.S.-CAST IRON < 115 BH			BRONZE - YELLOW BRASS			SERVICE	STOCK	TOTAL
ROUGHING r.h.		5/8-1" 3/4-1 1/4 1-1 1/2	28-14 8-4 4-2			28-14 8-4 4-2	14-7 4-2 2-1	14-7 4-2 2-1	4-2	4-2		84 32 12	42 16 6	126 48 18
ROUGHING l.h.		5/8-1 3/4-1 1/4 1-1 1/2	14-7 4-2 2-1			14-7 4-2 2-1	14-7 4-2 2-1	14-7 4-2 2-1	4-2	4-2		56 24 8	28 12 4	84 36 12
FINISHING		5/8-1 3/4-1 1/4 1-1 1/2					14-7 4-2 2-1					14 4 2	7 2 1	21 6 3
FACING r.h.		5/8-1 3/4-1 1/4 1-1 1/2	28-14 8-4 4-2			28-14 8-4 4-2	14-7 4-2 2-1	14-7 4-2 2-1	4-2	4-2		84 32 12	42 16 6	126 48 18
FACING l.h.		5/8-1 3/4-1 1/4 1-1 1/2	14-7 4-2 2-1			14-7 4-2 2-1	14-7 4-2 2-1	14-7 4-2 2-1	4-2	2-1		56 24 8	28 12 4	84 36 12
BORING		⌀ 10" 14" 5/8" 3/4 1 1 1/4					12-6 12-6 12-6 12-6 2-2 2-2			4-2 4-2 4-2		12 12 12 16 6 6	6 6 6 8 4 4	18 18 18 24 10 10
BORING FACING		⌀ 1/2" 3/4 5/8 3/4 1					12-6 12-6 12-6 12-6 2-2			4-2 4-2		12 12 12 16 6	6 6 6 8 4	18 18 18 24 10
ROUND NOSE		r = 1/8" 3/16 5/16 1/4					10-5 10-5 10-5 5-3					10 10 10 5	5 5 5 3	15 15 15 8
GROOVING OFFSET r.h.		l = 5/64 1/8 3/32 1/4 SECT. 5/8 x 1"					10-5 20-10 10-5			4-2		10 20 4 10	5 10 2 5	15 30 6 15
GROOVING OFFSET l.h.		l = 1/8 1/8 SECT. 5/8 x 1"					20-10 10-5					20 10	10 5	30 15
RADIUS FORM		r = 1/8 = 1/16 SECT. 5/8 x 1"					10-5 6-3					10 6	5 3	15 9
GROOVING INTERNAL		l = 1/8 3/16 5/16 SECT. ⌀ = 3/4"					6-3 6-3 6-3					6 6 6	3 3 3	9 9 9
GROOVING RADIUS FORM		r = 1/8 3/16 SECT. ⌀ = 3/4"								4-2 4-2		4 4	2 2	6 6
THREADING WHITWORTH		⌀ = 1/2"					20-10					20	10	30
THREADING SQUARE		⌀ = 1/2"					8-4			4-2		12	6	18
THREAD. ACME		l = 0.000" 0.007 0.0[illegible] 0.[illegible] SECT. ⌀ = 1/2"					2-2 2-2 2-2 2-2					2 2 2 2	2 2 2 2	4 4 4 4
											TOTAL	765	390	1155

Fig. 9.—Table of order for high speed and tungsten-carbide tools for small shop of 20 lathes.

with small means may choose to get the benefit of the super-rapid tools. The research shows that for the different classes of raw materials for the very best application about five different cutting angles of the tools are required (German proposition AWF). (Fig. 8.)

The author can state from his own experience in recent years

that two to three kinds of grinding for all common cases are sufficient to profit by the good qualities of the super tools. After some time a completion must take place by some special cutting angles which a good management may concentrate on a few machines for which special application of angles will then become standard.

A small calculation will show the expenses (Fig. 9). In a factory with 20 lathes we gave to each turner two tools right and one left of the ordinary commonly used shapes, for personal use, and kept the special one in the store-room for common use. The lathe department with 20 machines has been working for about six months to the greatest satisfaction and has a total of 1,165 of these tools in use. The tools have soldered tungsten-carbide bits. The

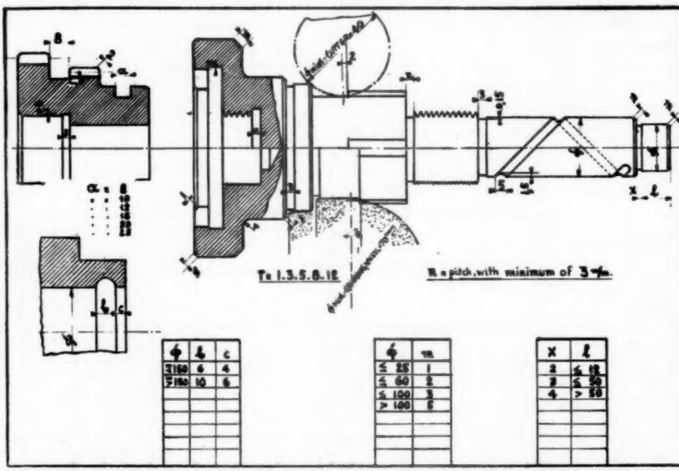


Fig. 10.—Prescription for the drawing office, with regard to special shaped tools.

finished tool costs (shank, bit, soldering, and grinding) about 17s. per tool for medium size of 3 to 4 in. by $1\frac{1}{4}$ in. which gives a cost of 17 by 1,165 =20,000s. or £1,000. This expense seems reasonable even for a small factory. It will be depreciated in less than a year, and then it will be of constant profit.

Of special difficulty are the common tools on account of their special shape for fillets, inner and outer, parting tools of sharp and round shape, tools for cutting threads according to Whitworth, Sellers, SI Acme, and Square Systems. These difficulties demand that a compromise is made between the drawing office and the shop, i.e., between what the office designs and what the shop wants. The best solution is the standardisation of the special tool-forms for

the use of the designer. A limit in design is established but it is the fundamental condition for quick work with high speed tools. Fig. 10 shows a scheme which has to be followed by all designers, when they inscribe into drawings, fillets, roundings, cut-ins, etc. Thus they help the shop, which otherwise could not get along with a small number of special tools, and all profit by it. The steel works get a great number of new orders for tools and the small user has the full profit of the new tools without great expense.

A Research Institute which does practical work, will give all the information as to the right grinding of the tools.

Lathe and planer tools of tungsten-carbide style are generally ground twice and then lapped, three operations with costly grinding

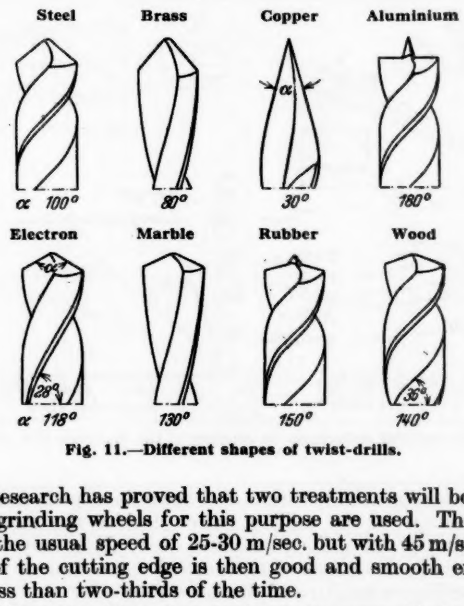


Fig. 11.—Different shapes of twist-drills.

wheels. Research has proved that two treatments will be sufficient if special grinding wheels for this purpose are used. These do not run with the usual speed of 25-30 m/sec. but with 45 m/sec. and the grinding of the cutting edge is then good and smooth enough and done in less than two-thirds of the time.

Twist drills. It will be best to have for every kind of material a special shape of twist drill (Fig. 11). This is very seldom the case as the primary costs are too high and the administration difficult. Yet one should have three different types of twist drills :—

(a) Drills for cast iron and steel.
(b) Drills for copper alloys (brass).
(c) Drills for soft light metals.

In all cases it is possible to form the drill so that it has, even with very deep holes (10 times diameter) a constant thrust of feed and a twisting moment minimum. The research for the best shapes for drills, which is of very great importance in those factories with mass production, can only be done systematically by a careful investigation of all working conditions. The right shape is the economic success.

In milling, the helical shape of the cutting edge is of decisive importance. It decides the forces :—

(1) In the direction of the feed.
(2) In the vertical direction, and
(3) In the direction of the axis.

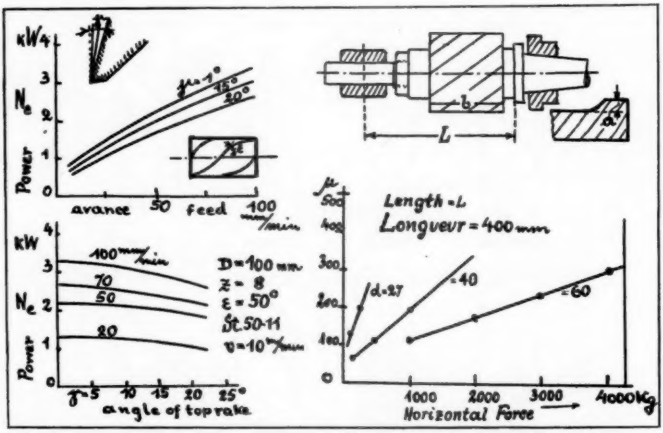


Fig. 12.—Forces and deflections in relation to the diameter and the length of a milling arbor.

As there is often the question of thousands of pounds of pressure, the right shape of the milling cutter decides the stress and the right working of the milling machine itself. It is easy to show the influence which the stress of the cutting forces has on the milling arbor according to length and diameter (Fig. 12).

The grinding wheel has quite a special place in production, for it is the only tool which is required to keep sharp always, though it is constantly being worn down. It is therefore necessary to make the right choice for the bond and the grain, and necessary to find laws for the speed and the feed between the material to be machined and the grinding wheel, which make the right choice of the wheel possible. Another point of importance is the fact that a wrongly

chosen grinding wheel not only gives bad work but demands up to double the power. As this consumption of power is very great, expenses result which are very often not taken into consideration.

This leads to the last part of this lecture, the research of the machine tool. We must measure the forces during cutting and for this purpose the apparatus shown in Figs. 13 and 14 is used for all ordinary machine tools. Further we must be able to compare the input of electric power of the motor with the effective work done by the tool. This gives the degree of efficiency resulting from the quotient: $\frac{\text{cutting action}}{\text{electrical energy}}$ The investigation supplies the proof

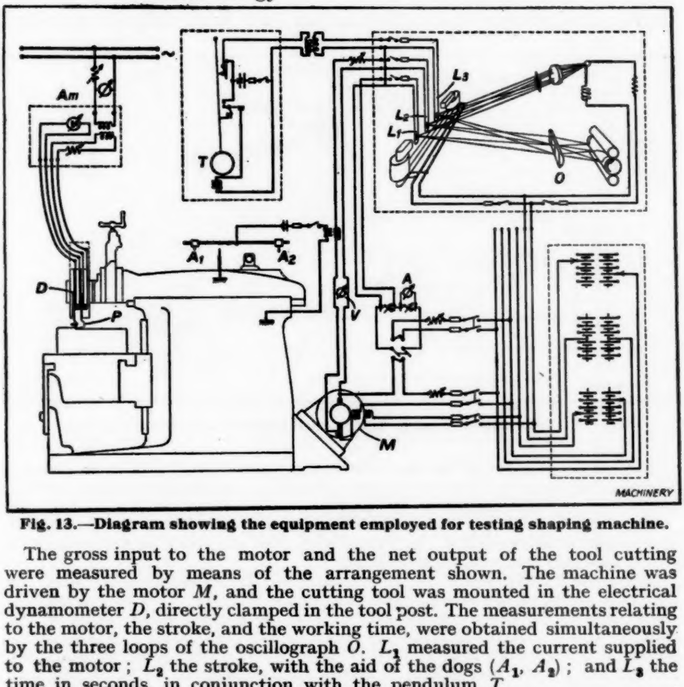


Fig. 13.—Diagram showing the equipment employed for testing shaping machine.

The gross input to the motor and the net output of the tool cutting were measured by means of the arrangement shown. The machine was driven by the motor M, and the cutting tool was mounted in the electrical dynamometer D, directly clamped in the tool post. The measurements relating to the motor, the stroke, and the working time, were obtained simultaneously by the three loops of the oscillograph O. L_1 measured the current supplied to the motor; L_2 the stroke, with the aid of the dogs (A_1, A_2); and L_3 the time in seconds, in conjunction with the pendulum T.

At the same time, the horizontal cutting force exerted by the tool was measured independently by the ammeter Am. The gross power input to the motor and the net output of the tool could be compared directly by this method.

The force P (power component) was measured by the dynamometer and the input to the motor, for the varying sections of chip by wattmeters.

if the tool is correctly shaped, for then it uses the least power. Besides, we have a control if the machine tool is well designed and well manufactured. Then it has the least losses in the gears, consequently the best degree of efficiency. We shall try to design a testing apparatus which allows us to find directly the balance between the motor and the tool in one investigation. That tool is the best which cuts the easiest without producing unnecessary heat. With the right tool on a shaper the white chip was increased in section from $4 \times 1.5 = 6$ mm^2 to $6 \times 2 = 12$mm^2. That is, double without changing the drive of the machine at all.

The best machine is that with the best mechanical degree of efficiency and the simplest service. The comparison of the variable degree of efficiency of an idle running lathe with different numbers

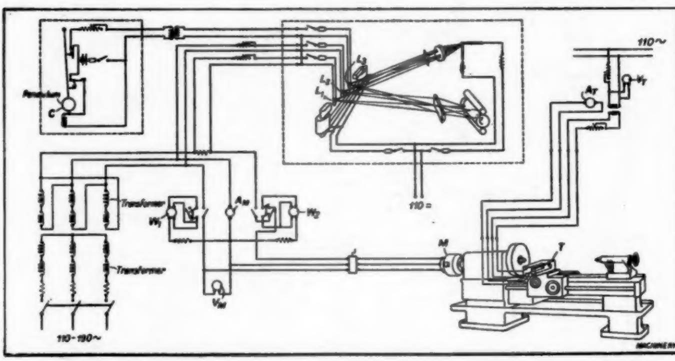


Fig. 14.—Diagram of electric testing equipment employed for a lathe.

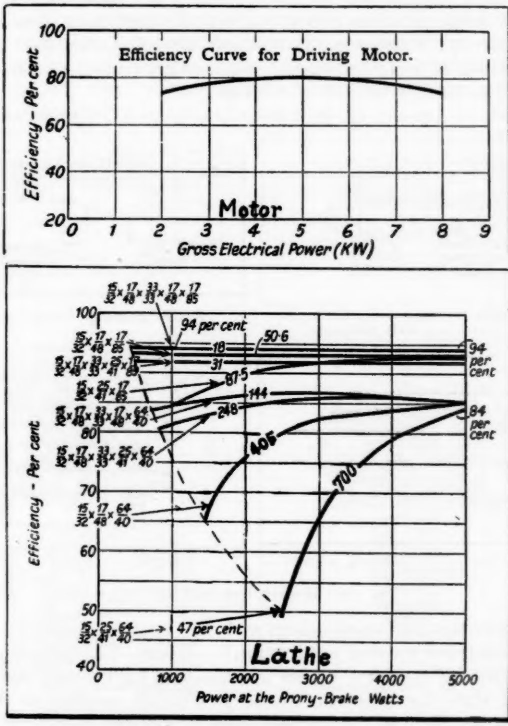
The electrical input of the motor was determined by the two-wattmeter method ; at the same time the mechanical power was measured with a prony-brake on the main spindle.

The efficiency of the motor itself was measured with a dynamo-brake. It is possible to determine, by subtraction, the efficiency of the headstock alone, as a function of the power input.

Next, the cutting effect of the machine was compared directly with the electrical input of the motor. In the diagram Fig. 14, T is the measuring dynamometer for the three components of the cutting force acting at the tool, A_T and V_T are the instruments for obtaining the reading of the dynamometer, M is the motor, A_M, V_M, W_1, W_2 are the instruments for recording the current supply to the motor, C is the time pendulum. The oscillograph employed (Siemens & Halske) has three loops L_1, L_2, L_3, and permits of comparing the net cutting output with the gross electrical input of the motor, the time being recorded in seconds.

The dynamometer T (Wallichs), for measuring the cutting forces, employs the well-known electro-magnetic coil system, the different pressure being indicated by the change of the mutual induction.

of revolutions of the total range (17 to 700) to the nearly constant degree of efficiency of the motor with only one speed, does show the difficulties of our problem (Fig. 15). It is easy to design for one number, be it as high as possible, for the right bearing will work with the right lubrication and the right adjustment. It is very



Efficiency Curves for Each Spindle-S-eed of the Lathe

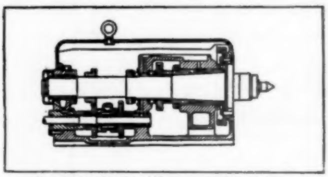
Fig. 15.—Efficiency curves for each spindle-speed of the lathe.

difficult to design a bearing if the same spindle in one minute has to work with 20 revolutions and then with 2,000 (Fig. 16). Another difficulty is that the unilateral charges from outside by bending moment and pressure according to the section of chip fluctuates greatly from 6 kg. with a fine finishing cut of $0.3 \times .01 = 0.3$ mm².

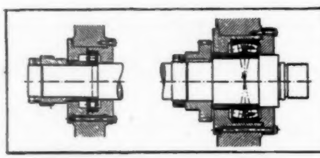
up to 2,000 kg. for a heavy roughing chip of $8 \times 1.5 = 12$ mm.^{2}, so that the position and the shape of the main spindle change greatly. The problem of the bearing with the right lubrication is also that of elimination of vibration, and the production of a proper surface. A shop which has, e.g., to manufacture lathes and grinding machines, has to make designs for bearings which vary according to the size of the machines between 10 revs./min. and 80,000 revs./min. (Fig. 17).

The amount of research is nowhere so comprehensive as in the investigation of machine tools, and nowhere has it been so much neglected as in this branch of science.

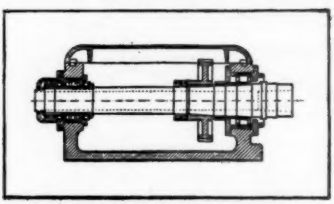
We live in an age of enormous production possibilities, in the



Headstock Oerlikon—conical bearing with two ball bearings.



Roller bearing—John Lang.



Cylindrical roller bearing adjustable in front.

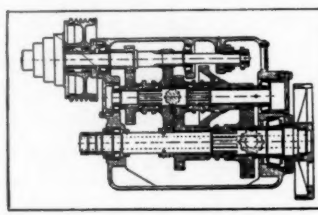
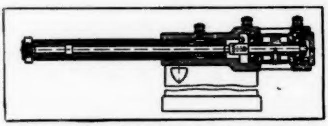


Fig. 16.—Modern bearings for lathes.

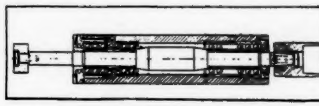
age of abundance in comparison with the former periods of scarcity from the point of view of production engineers. The farmer produces by his artificial manure, by his machines of harvesting and sowing, so much, that the greatest wheat producing country of the world must destroy 25% of its harvest, and a country having the greatest fishing results must throw a good deal of its catching back into the sea, while the country having the most coffee must burn or sink many millions of bags. Greece has to destroy her crop of currants and so on. In all the world there are about 30,000,000 people unemployed who live scantily.

We observe further that a good part of our enormous capacity of production is engaged to-day in the direct manufacture of unproductive things such as tanks, guns, shells, munitions of all kinds, and that the superfluence of money is used for things of which

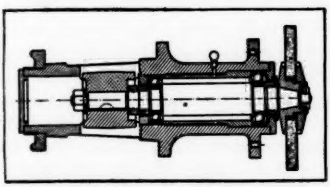
all producers hope will never be used. All this is done without the endeavour to raise the standard of life which should come first of all for the poor people. Every one is convinced of the fact that these conditions in life must soon have an end, but what does not reach its end, but has increased enormously by the production of unproductive preparations for armament in all the world, are the best machine tools and tools. It has been the aim of this evening to show the means which sensibly increase the efficiency of machine tools, with the help of systematic science. It is unthinkable that the end of all this work shall be that international markets



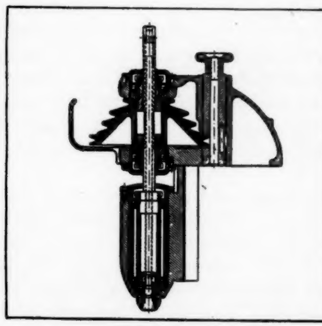
Internal grinding attachment, 20,000 rev. plain bearing in front.



Internal grinding attachment, 50,000 rev. ball bearings. Tempo Mueller-Nurnberg.



Main spindle of grinder—small axial force.



Small vertical milling machine, Reed-Prentice, 10,000 rev.

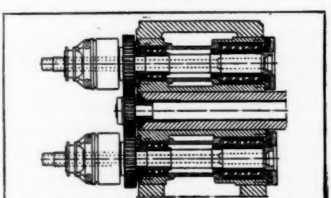


Fig. 17.—Ball and roller bearings for the highest number of revolutions, grinding, milling-screw machines.

seclude themselves more and more by duties, contingents, defence of imports, trade economics of the foreign exchange, etc., while in all countries the capacity for the installations of machine tools increases rapidly, always more than the use of goods. It must lead consequently to an increase of unemployment in the economical system of our days. This leads to the demand for right distribution

of the goods we manufacture in growing quantities, which must go hand in hand with an improvement of the standard of living of the working classes. That is the aim of the producing activity and of the science on which it is founded, the science of the machine tool and the tool. Science always means progress and improvement of our knowledge in the service of mankind and its welfare. There is no exception to this rule, although unfortunately machine tools and tools are bound so narrowly to material and economic questions. This must in no case hinder us from endeavouring to reach perfection. That nation, however, which will profit in the best and quickest way by the use of science will serve its own population and bring them to a position above that of the other nations of the world.

Discussion, London Section.

Mr. W. Puckey (Section President, who was in the chair): I think you will all agree that Dr. Schlesinger has given us a very fine lecture, and if we take advantage of all the ideas and information we have heard this evening our factories will be better and more efficient places to work in.

Mr. Blackshaw: I would like to say first of all that I believe this to be the largest gathering that we have ever had, which is in itself an indication of the interest which Dr. Schlesinger's paper has aroused. When I first noted the title of the lecture I formed the opinion that it would probably be just one of those interesting academic discussions, but I am now thoroughly convinced that what probably to many of us on the surface appeared to be purely academic, is in fact intensely practical.

I was particularly interested to learn that his methods have been applied to a shop of only some 20 lathes, for, as we all know such small shops invariably resent anything which has the slightest pretext to being academic, they being firmly convinced that such methods could have no useful application in such small shops. One can, therefore, quite readily understand that if such investigations as indicated by Dr. Schlesinger can be of practical value in small establishments it does not require much conception to appreciate the savings that could be effected by adopting his methods in the larger establishments.

I found the various curves which were shown on the screen to be particularly interesting, especially those which indicated the power absorbed by various tools, for it showed clearly that a good deal of waste takes place when related to the actual power absorbed by the cutting tools. Such a case clearly indicates the need for research along the lines indicated by Dr. Schlesinger. I was also interested in the slides which showed the various machines set up for carrying out the various tests which we have heard described this evening, but it was rather disturbing to learn that all these machines were made and installed on the continent.

As far as my knowledge goes we have certainly nothing in this country which would allow of such extensive tests being carried out, and there is no doubt that if we as a nation ever wish to have a predominant place in the machine tool industry, it is imperative that some such facilities are available in our own country. It would appear, therefore, that there is a real need for an organisation to be set up as a central body where manufacturers could submit their problems and obtain such data as they require, and I cannot think

of anywhere where this problem could be cradled better than within the walls of our own Institution.

Mr. Loxham: I should like to add my tribute to the wonderful work that Dr. Schlesinger has done. There is no doubt that in years to come production will be looked upon as a very scientific study, and I think to-day we look upon one of the pioneers in the great work of transforming production from an art to a science.

One hesitates to mention things that Dr. Schlesinger has not referred to, realising that in a single lecture, only a part of the subject can be covered. I was rather surprised, however, that he did not refer to the relationship between speed and feed. He has mentioned that for various materials one can obtain by means of experiment, the most efficient speed at which a material can be machined. In any such experiment one has to assume a certain feed. I have recently carried out tests in which a machine was run at a certain speed and the feed progressively increased until the tool failed. This test gives a combination of speed and feed just above that which that tool will stand. A slower speed can next be tried, progressively increasing the feed until the tool fails again. This can be done many times to obtain a number of results giving a combination of speed and feed, each of which will give an equal tool life. If these results are plotted, they lie on a smooth curve, and as far as tool life is concerned, it makes no difference which combination of speed and feed is chosen. The problem then arises, which shall we choose? Using the data obtained, it is a simple matter to calculate the cubic inches of metal removed per minute, and this data can be used to plot a second curve. These curves show quite definitely that the maximum removal of metal per minute for a given tool life is obtained by having a slow speed and a heavy feed. If this is so, why not always use a heavy feed and slow speed? An examination of the work will show that cutting under such conditions produces a very rough finish. If one uses the cutting tool dynamometer of the type that Dr. Schlesinger has described—which, by the way, we have at the Northampton Polytechnic—one finds that the pressure on the tool under these conditions is very high. The resultant pressure on the work is high, and the job often determines the maximum feed which can be used. It is obviously not permissible to use a very heavy feed when turning a $\frac{3}{4}$ in. diameter bar 16 in. long, because the bar will spring out of the lathe, and so on. It seems clear to me that we should examine our manufacturing problems, not as to the speed at which we should machine a job, but as to the feed which it will stand, and then knowing the feed, from a curve which can be obtained with considerable precision, read off the economic speed. Dr. Schlesinger has shown a slide giving the shapes of tools. I should like to know where further particulars of these tools could be obtained.

In the *Machinery* issued on May 20, 1937, there was a short article by Dr. Schlesinger on "Practical Tests on a Lathe," and some of the diagrams which Dr. Schlesinger has used to-night were taken from this paper. The article in *Machinery*, though short, was very good. I should like to know from Dr. Schlesinger where one could obtain a full report on this test.

I was rather surprised to see the curve that Dr. Schlesinger put on the slide indicating the changes in the rate of speed of certain foreign machine tools. I have examined a number of English machine tools, examined the speeds, plotted them, and found them, with very few exceptions, to be in true geometric progression. I do not think that the English machine tool makers make quite such serious errors as the foreign tool maker to which Dr. Schlesinger referred.

Dr. Schlesinger: Mr. Loxham asked first for the relationship between speed and feed. Not the relation between feed and speed is decisive, but the allowances of the forged or cast rough piece and the quality of the surface which is wanted. The measuring of the production by the weight of the chip is not any more usual nowadays, because we take the allowances as small as possible as well in the forge as in the foundry. We have generally one roughing chip but always several passages for finishing. Sometimes this roughing chip is even so small that work is quicker done with high speed and small feed than reverse. The relation of 5 : 1 for the depth : feed demands already heavy feeds. Generally the shop chooses for machining steel 10 : 1 and takes for cast iron 5 : 1 or 4 : 1. In most cases the design determines the shoulder between two diameters and the machine tool must be so designed that one is able to do with the machine heavy roughing cuts, i.e., great forces with tough high speed tools and medium speeds, but all the light roughing and the ordinary finishing cuts are taken economically with the cemented tungsten carbide tools: high speeds, and fine feeds. In the well-known book of F. W. Taylor from 1903, on the "Art of Cutting Metals," you will find historical statements on the relationship of speed and feed. But they do not fit our problem of to-day, which is "speed." Further you will find in the booklet of H. Klopstock, of 1926, published by the laboratory of Charlottenburg, "Die Untersuchung der Dreharbeit," the best study on the relationship of depth : feed for the reciprocal sections 10 : 1 and 1 : 10, 10 : 2 and 2 : 10 etc. up to 10 : 7 and 7 : 10. Heavy chip sections produce blue and red hot chips and this is the worst and most expensive kind of producing heat.

Fine chips and quick speed correspond to small cutting forces and a small stress of all elements of the machine tool, but they demand great power, well designed bearings and vibrationless constructions of the beds and uprights. Further, the shape of the piece and its lack of rigidity forbid to take heavy cuttings. Interruptions

of the surface by holes and slots can be easily machined by light cuts and high speeds, but with great difficulties by heavy feeds and slow speed or not at all.

Finally, if you have to machine single pieces, as in the shops for big machines in dockyards and in all repair shops, you have to rough and to finish in one setting. This you can do on old machines by turning, filing and using the emery-cloth, but only on modern machines by rapid turning with cemented carbides.

The second item was the correct shape of cutting tools. I refer to the publications of the German Standards Committee, sheet No. 770,771 and 4951-4963.A short publication you will find in ***Machinery*** Vol. 48, Aug. 6, 1936.

The third item referred to the speed chart of machine tools. Most machine-shops have a medley of old, younger and modern tools. The majority is as far as my own experience of the three last years reaches equipped with tools of ten to twenty years of age. With the machines of middle age, I am sorry to say, you have sometimes not only badly stepped progressions, but much too slow speeds to exploit the modern tools.

As last question Mr. Loxham asked me for the full report on my " Practical Test on a Lathe." This has been published in the French paper " Machine Moderne " July, 1937, page 569.

Mr. Whitehouse : Dr. Schlesinger's enormous field and description of difficulties that face us in arriving at something in the way of data from the point of view of time is rather melancholy to me, because during the past twelve months in the process of studying possibilities of colour controls we at the Austin Motor Company have been faced with the proposition of furnishing straightforward concrete charts similar to the one which Dr. Schlesinger put up at the head of which were the speeds capable of being obtained on various machines. Unfortunately, I find we shall want about 10,000 columns on that chart so that my optimism when the chart first came up has rather cooled off.

In the process of trying to obtain these charts or this data to supply more accurate information when we were trying to instal colour controls we first tackled drilling machines. We found that everyone in the works practically had a chart, quite a good authentic chart, which gave various speeds in feet a minute for drilling at from 70 to 120. Well, we took a chance of an average speed of 90 feet a minute, and having arrived at that we made the usual type of little chart which gives you speeds for diameters, and we found that it was an absolute impossibility to apply that chart to anything out of an incalculable number of machines in the factory. For instance, on a $\frac{3}{8}$ range on a sensitive drilling machine tapping at say 20 ft., reaming at a little over, and drilling at 90 ft. a minute we wanted no less than 40 speed changes, and as most of our drilling

operations carried out in that class of machine are carried out in a matter of thirty seconds, forty seconds, some five seconds, and so on, which includes loading and handling, we could not stop the machines to make the change so that those 40 speed changes had got to be automatic. If Dr. Schlesinger can tell me if there is any machine of that type on the market or in the process of development, or if there is any prospect of that machine ever coming into being I should be very grateful.

As regards turning, we got very deeply in the soup here. For instance, Taylor tells us that we can rough at 133 ft. a minute and we can finish at 420 ft. a minute. Well, that is rather a big tolerance. And then we turned up another handbook and they offered roughing at 200 and finishing at 250, and then our friend Ward roughed at 90 and finished at 200. Well we took a chance again and we tested with a $^{3}/_{16}$in. cut and a .010 in. feed with a speed of 150 ft. per minute. (DR. SCHLESINGER: For drilling?) For turning. Having got 150 ft. per minute for a $^{3}/_{16}$in. cut and a .010 in. feed we were then faced with wanting a formula, either a straight-line formula or a curve, for arriving at high speeds for skimming cuts and slow speeds for hogging cuts. We found at the time Dr. Kronenberg had an article in "Machinery" in which he gave us a ready-made formula with a constant for various materials and for mild steel. This constant was 2.44 and then we had to multiply the chip area, that is the size of the cut, by 1,000, take it to the K route, K being the constant 2.44, and that gave us a figure which we had to multiply our rates by in order to arrive at the correct cutting speed for any cut on that class of material. Well, again we had to revert to various authorities and all differed as to the respective speeds which we could use for various classes of materials. We have certain standards at the Austin Motor Co. and as a result we were able to make a chart and on this chart we put along the top diameters, and we put down the side various materials, so that we could read off and find visually the exact speed at which it was required to calculate the turning time for any job. Before taking any rash steps with it we turned out, well, hundreds of demonstration sheets, that is to say, sheets which had been carefully entered up by our demonstrators in carrying out demonstrations before putting new machines in the works, and we found that it absolutely wrecked our chart. Some types of cuts that were vibrationless took us right outside the chart and certain heavy turning operations took us right down below it, and as I say quite a lot of our turning operations are very little more than actual cutting time, and we dare not risk any discrepancy that might arise. Ten per cent. would have been very, very serious up or down.

So we are now left suspended in the air with a good chart built on the best data we can find, and unfortunately Dr. Schlesinger has

confirmed all our weaknesses. I would like, therefore, to ask Dr. Schlesinger whether he thinks that the obvious variables which contribute to make that chart are not solvable, and solvable in a reasonable time, and whether we could remove them ourselves or whether it is something which is going to remain in the nature of a national proposition ? There is one danger in tackling that problem, and that is that alongside the charts that we already have Dr. Schlesinger might give us another one which would not cancel out the others. Actually that is the difficulty we have, and that to us is the result of about twelve months' intensive concentration on one particular problem.

We are not much concerned about materials. The Austin Motor Co. runs a standard of materials of a known content which we get in fairly big bulk, and are therefore very seldom variable and are materials which can be regarded as standard. Also we do not have much difficulty about getting machines.

DR. SCHLESINGER : How many kinds of materials do you use ?

MR. WHITEHOUSE : I can give you the actual figure. We have 13 principal materials. I have not included bronze, aluminium, or any non-ferrous material—and they vary from mild steel with a brinnel of 5.3 to manganese and nickel alloys with brinnels treated for machining of about 3.8.

DR. SCHLESINGER : What is the tensile strength of the materials ?

MR. WHITEHOUSE : The tensile strength of the mild steel is pretty high. Our mild steel runs at about 31 tons, and the tensile strengths of the other materials, the best materials, are about 51 tons. Regarding the spindles and machine tools generally we regard that as the problem of the machine tool manufacturer. They give us machine tools far better than used to be the case, but we have tested them with the Schlesinger Machine Tool Tests with rather disastrous results to the machine tool maker. We got 200 major rejections out of 275 machines, all of which are free of charge and none of which came under the heading of damage in transport.

There is just one point I should like to mention to Dr. Schlesinger which is not at all relevant to the remarks just made. He showed a very interesting slide in which he enlarged on the importance of the rigidity of the milling machine arbor. I would like to give him our experience along those lines. We put in 17 new milling machines rather larger types than before. We purchased the machines less arbors and we put round arbors which varied from about 2 ft. to 2.5 ft. When we came to operate the machines we found that the arbor support is bolted on to the front of the knee, that is, the brace or side is bolted on to the front of the knee, we could not apply that brace to any of our milling operations, so we fetched the Cincinatti people in and they told us that they needed 3 ft.

arbors, and we must not use them shorter; so it appears that Dr. Schlesinger and the principal machine tool manufacturers rather diverge there. Of course we could get over that by changing the inside diameters of cutters, but these, as you know, are usually governed by their outside diameters.

MR. F. GROVER: There is one difficulty which I should like to voice, that is, that Dr. Schlesinger, with his knowledge of French and German, is able to tap a great deal of foreign literature which is not known to us in this country. One of the ways in which we could get the utmost value out of the very fine lecture that we have had this evening would be to think of ways in which we could get the information in such a form that we can calmly read it over and digest it. I think one of our functions should be for this Institution to gather together such information so that it can be more fully studied by the members.

MR. CRITCHLEY: I would like to ask Dr. Schlesinger what power he would recommend for a 10 or 12 in. centre lathe to take the highest utility out of the tungsten carbide tool. I recently had experience of an English machine and we were unable to get sufficient power through the headstock. I would like to know what he recommends on that point.

DR. SCHLESINGER: Which height of centres?

MR. CRITCHLEY: Ten inch centres. The trouble was that on a job about 8 in. diameter we could not get anything like the speed because the motor would not drive. That was connected up for the power recommended by the actual makers of the lathes.

Whilst appreciating the work that lies behind this lecture, there was a previous speaker who mentioned that England did not seem to have done anything in this matter at all. I would like to tell him that in the Manchester Technical College similar research work to this was carried out, even if not to the same extent. I am afraid I cannot just remember the Professor's name.

DR. SCHLESINGER: Professor Dempster Smith. That was before the war.

MR. HALES: I would like to make reference to the fact that the Institution of Production Engineers has for a long time given serious consideration to the problem of research in production engineering. The subject covers a very wide field, and machine tool and cutting tool appear to be an inseparable factor in any research scheme in production engineering.

The difficulty appears in the first place to find the money to back and support a research organisation, and at first thought it may appear that research work relative to machine tools, feeds and speeds and cutting tools should be carried out by machine tool makers rather than by users, but Dr. Schlesinger's lecture takes us far beyond this narrow view. He gives us examples of research

work carried out by firms on the continent, and from these examples it would appear that the manufacturers in this country are far behind their continental competitors, who are employing research work in machining problems in a way almost unheard of in this country. It is true, that many of our big factories have their own research departments to a greater or lesser degree, but there appears a necessity for concerted action in setting up a research organisation in production engineering which would benefit the industry as a whole.

There is no organisation more suited to initiate this research scheme than the Institution of Production Engineers. I think that everyone here is now convinced of the necessity for it, and for my part, I think it is a terrible state of affairs when a country like this should have to go to the continent for their information when we might have a central body to provide us with that information up-to-date for ourselves. Any practical steps to bring about such an organisation would benefit the whole engineering industry.

Mr. Gordon England : Mr. Hales has put in very terse and admirable phrases just the feeling that has been going through my mind in listening to this lecture, and I think I may say the encouragement we have had in the remarks of a member of such an efficient organisation as the Austin Motor Co. on the difficulties they have had to face indicates the dire necessity there is for some form of practical research organisation. There are many of us who think, not perhaps putting it in quite the words that Mr. Hales did, that it is a shame that we should have to go to the continent to obtain most of our information, and who would all agree that we ought to make our contribution—I would rather put it that way myself—to the sum of common knowledge on this subject which has been outlined so admirably this evening by Dr. Schlesinger : and what better body can there be than this body to foster that idea ? After all, we could do a great deal as an Institution in that direction, and in this praticular connection I would like to suggest that Dr. Schlesinger's paper would have put a greater power in our hands if in conclusion he had given us one or two charts and a small section setting out the economics of his researches, in such a form that they could be laid on the board room table. Now I say that, gentlemen, for this reason. It seems to me that if all the production engineers in this room, and in the country as a whole, who are members of our Institution, were able to put the economics of this situation before their respective boards, we might be able to raise a fund of considerable magnitude in a very short time, which would enable this Institution to father this research. I do think that such research should be fathered by an Institution which knows what it is that it wants, that has always got a growing need for the products of research. I think there is a very great danger in research not being properly

directed. The Institution of Production Engineers, if responsible for sponsoring the work, would make sure that such research is not static but dynamic, because all of its members are practical men who are up against practical problems day in and day out, and are moving with the times; and this fact will correct the inevitable tendency there is for research to become too academic and in consequence written down as being of little value. I would therefore suggest, Mr. Chairman, that this, perhaps, might be the subject of another paper, to take the economic possibilities of these researches and show what an immense bearing they would have on, shall we say, the balance sheet of companies, and then we might take them to our board rooms and get sympathetic support for a research fund.

MR. B. C. JENKINS: I think I have looked at Dr. Schlesinger's paper this evening from a different standpoint to the majority. I am of opinion that the lecture is indicative of the necessity to look at this question of production research from a national and international standpoint and not from that of one's own particular industrial environment. It is well known to many of us that the investigation upon which Dr. Schlesinger's paper of this evening has been based was carried out some years ago. In the meantime it is probable that other investigators who have not published their findings in the same open manner as Dr. Schlesinger have followed in his footsteps. It is known that other nations, particularly U.S.S.R., are already directing and financing activities along the same lines and to a much greater degree than Dr. Schlesinger was ever able to.

This country has so far seen fit to *follow* the same lines and methods developed by countries who are more alive to the necessity for national research than our own. Whilst agreeing the necessity for such research and investigation, I personally am of the opinion that it should not be left to the production engineers of this country to direct and finance the activities of such an Institution. It is essential for the Government and the industrial magnates of this country to finance and direct such activities, although our Institution may be the moving spirit in getting the work started. It would seem that we are wasting both time and money when carrying out research work in individual factories which are not properly equipped for the purpose.

I listened with some interest to our friend from Austins and the viewpoint he had arrived at on the basis of the research work they had carried out and then to the views of Mr. Loxham arrived at after both technical and practical research. The divergent views and the difficulties which arose in the course of their investigations can be answered in a very short time by a specialist of Dr. Schlesinger's experience. It appears to me that production engineers

actively engaged in the factories would never be in the position of having the spare time to aid in directing the activities of even a small institution engaged in research such as is required in the national interest.

DR. SCHLESINGER : Mr. Whitehouse mentioned colour control. This device controls only if your prescription is correctly set. But it is your duty to fix the correct speeds and feeds beforehand. Further, Mr. Whitehouse criticised a chart of 10,000 columns.

MR. WHITEHOUSE : No, that is not correct. I said that if we made a chart along the lines indicated by yourself we should require about 10,000 columns.

DR. SCHLESINGER: This is in the line of Mr. Gordon England's discussion, who stressed the point that all shop research must be economic and not academic. I have tried to give examples of practical work and not a professor's lesson. The chart (Fig. 1) has been introduced in January, 1937, in two shops, one with 1,200, the other with 500 workmen and has been proved well adapted to their actual working conditions. These you must find out yourself, of course, Mr. Whitehouse, just as the physician examines the sick people and selects the remedies after a carefully made diagnosis. I did not give you more than an example, and not a universal remedy.

A research institute can do two things—develop leading ideas which you have to adapt to your works, and investigate the special case together with you and find the best practical solution directly.

If I understand Mr. Gordon England correctly, he desires to replace dry and academic research, which he called "static," by dynamic research, i.e., to reveal its economic possibilities. This tendency must be proclaimed with emphasis. Mr. Critchley asked for the motor for a 10 in. or 12 in. centre lathe. The motor is generally furnished with the machine and its power cannot be changed.

MR. CRITCHLEY : I assumed that you could change it.

DR. SCHLESINGER : If you increase the cutting speed from 60 ft. to 180 ft. but keep the same section of chip, the motor-power must be tripled ! For a good machine of 10 to 12 in. centre you ought to have at least 8 h.p. The cutting force will be about 2,500 lb. for steel of 40 tensile strength, the heaviest section of chip = $\frac{1}{4}$ in. $\times$ 0.05 in. = 0.0125 sq. in. Changing to cemented carbides and therefore to at least 150 ft., you have to change your motor from 8 to 20 h.p. If the workman tries to exploit this lathe by heavy chips, f.i., 0.035 sq. in., after Mr. Loxham, but low speeds, f.i., 60 ft., he will smash all the gearing of the machine. These machines must be protected against ill-treatment, f.i., by shearing pins. This is a very great danger for our modern tools. Line shaft and belt avoid it. If the line shaft is running with 400 rev. instead of 200 the belt power is automatically doubled. You may have to change their

bearings and better the lubrication, and, of course, the driving motor for the line. The weak point of the older belt driven machine-tools is that they are generally designed for about 300 to 500 rev. (medium size of 10 to 14 in. centre). The charts I used in this lecture come from shops where we succeeded in speeding up about 150 older machine-tools to 500 and 750 rev. just by changing bearings, lubrication, and providing lubricants for cooling the tools. It is generally not possible, by lack of money, to replace all the old-fashioned machine-tools by new ones and it is not even advisable, with regard to the depreciation account, for the heavy machines.

The advantage of super-rapid and cemented carbide tools is a double one. You diminish the time of machining and the time of grinding the tools.

Mr. Whitehouse mentioned the drill press with 90 ft. for drilling and 200 ft. for tapping : well, the Asquith people demonstrated to me at Halifax one inch drill with 150 ft. for drilling and 75 for tapping in cast iron.

MR. WHITEHOUSE : 75 ft. a minute ?

DR. SCHLESINGER : Yes, I have measured it myself. Tapping depends on correct grinding of the tool before all. Then Mr. Whitehouse said that his machines had 40 speed changing possibilities.

MR. WHITEHOUSE : Would require it.

DR. SCHESLINGER : Would require it ! Mr. Whitehouse, I am an old shopman. That is the wrong way to look at the problem. To-day, with these modern tools, you have the possibility of increasing the speeds three to 10 times. The total range is increased, consequently you can exploit your machine part to its maximum, without 40 changes. This general higher level produces economy. Be satisfied with 30 to 50% benefit in machining, and do not try to get the utmost out of each single case. The ratefixing department must work quickly, and these hustled men can only follow by universal rules. A total gain of 30% would allow to occupy 70 men instead of 100. This is of great importance when hands are exceedingly short.

You mentioned the formulae of Kronenberg. Each formula has "factors," these factors are found by making experiments on certain raw materials. If these are different, you cannot use the formula. Just for this purpose the Research Institute is the right place, as most firms have their own materials and do not like to publish their physical and chemical properties which determine the factors of machining. As these materials are changing from time to time, the same as the materials for tools, the problems of research are never at an end.

MR. CHILDS : As Chairman of the Graduate Section and on behalf of the London members gathered here, I wish to convey our gratitude and compliments to Dr. Schlesinger for a very interesting

lecture. There is no doubt that, as Mr. Loxham has said, the art of manufacturing machine tools will be raised to a science. Even should that not completely take place in the lifetime of the older members, it will come.

Discussion, Manchester Section.

MR. F. W. SHAW: In dealing with the question of cutting speeds and feeds in relation to output, our speaker seemed, in my opinion, to have concluded that the output depended solely on speed and feed, whereas in practice there are far more important factors. There is, for instance, the machine equipment factor. If you merely increase the speed and feed, you decrease the cutting time and nothing else. But the cutting time is often by far the lesser portion of the total time. So that the labour expended on the illustrated charts intended to enable an operator to select the proper cutting speeds and feeds for different tool angles might possibly have been more profitably devoted to providing means for improving what might be termed " idle " factors.

DR. SCHLESINGER: If you speak of the equipment of the machine tools you evidently think of jigs and fixtures, setting-up and handling. All this I take, if I speak of machine tool research, as a matter settled beforehand. This is the task both of the designer of the machine and the organiser of the shop. You may be able to improve the clamping device of an old machine by replacing the old chuck by pneumatic, hydraulic or electrical means, but you cannot change the handles and the manual service as a rule. But very often you can recondition the older machine to fairly modern speeds. You have to change their bearings and their lubrication and means of coolants. For the modern machine the increased speed of cutting and the quick attendance are the basis from the first. This is of psychological importance too, as increased speeds and feeds influence automatically the agility of the workman in every respect. Everything is done quicker! He who intends to cut in $\frac{1}{3}$ of the former time, will adapt all fixtures and their manipulations to the speeding up. When the production engineer makes the plan for the operation for any piece and is obliged to use old machines, he is improving the process of machining by designing the most important time-saving devices.

The time study divides any job into the time of setting up and of machining. You will find that specially for shearing and punching machines (sheet iron), the cutting times are very small. about 10 to 20% of the total time. This cannot be changed, but in spite of this fact the designer endeavours to increase the cutting speed of these machines. The main point, however, in using tungsten carbide tools is the fact that the cutting edge remains sharp very much longer than ordinarily with high speed steel—one day, a week and even longer. This fact reduces the grinding

and resetting of the tools considerably and above all prevents the unproductive idle time of the machine. The resetting of a turret lathe or an automatic screw machine takes hours. If you selected the correct and well adapted cutting speed, given by research, the ratefixer could care for keeping the tool sharp until the piece or a number of pieces had been finished. The adaptation of the life of the cutting edge to the job is the main object of the problem.

Mr. A. E. Ingham: I would ask from what channels Dr. Schlesinger has been able to accumulate all this valuable information? It seems to me that it is a very difficult problem to co-ordinate three such widely different factors as the tool, raw material and the machine tool. I know it would be appreciated if Dr. Schlesinger could tell us how this information has been accumulated. In these three factors you have, on the one hand, the man who makes the material and does not care "two hoots" how you are going to machine it, then the tool maker, who is not particularly concerned with how it is going to be applied, and the machine tool designer hoping for the best and following the other two.

I carry my mind back to the earliest experiments during the advent of the high speed steel tools by Professor Dempster Smith. That information set a standard which became a classic, and that information was available to the whole industry and appreciated by all concerned. Dr. Schlesinger in his numerous activities has given us tests and alignments which are regarded by many inspecting engineers, and particularly the Russians, to be the information the engineering world had been looking for. There are others who do not regard these standards so favourably, but personally I think it has been proved a most valuable contribution to the engineering industry, and I also think the information given by Dr. Schlesinger to-night is an equally valuable contribution to the industry. I am very interested to know however, how the three factors have been co-ordinated so successfully.

Dr. Schlesinger: The three points of which Mr. Ingham spoke, raw material, tool and machine-tool, have been joined to a unity by the Charlottenburg Research Institute in the following way: Tool and machine tool belong together, and cannot be separated. A man who is designing a lathe, a drill press, a milling machine, etc., must know thoroughly, by actual practice, the manner of cutting of the respective tools. The tool signifies for the machine tool what the steam is for the steam engine, the electricity for the motor, etc. It is the basis both for the design of the machine and for its economic exploitation.

The former leader of the Charlottenburg Research, the reporter of this evening, spent of the forty years of his tool practice, almost eight years in designing, manufacturing and in using tools and

machine tools in actual practice, and more than thirty years in the investigation of raw materials, tools and machines, both in his research laboratory and in permanently using them in his position as consulting engineer and as shop organiser. Out of this practice arose the following functions, which give at the same time an answer to Mr. Ingham's questions.

The special standards committee of the Association of German Machine Tool Builders (Verein Deutscher Werkzeugmaschinenfabriken—VDW) was founded 1911. This Association treated all the questions of tool and machine tool with the aim to make them useful for all industries. In 1917 the German Standards Institution (Deutscher Normen Ausschuss—DNA) was founded. The leader of the Research Institute got here the position of reporter in all tool questions and a permanent place in the board of DNA.

VDW (corresponding to the British Machine Tool Trades' Association) prepared the work. DNA (BSI) finished the standards' sheets and published them. The reporter had a decisive influence on all resolutions.

We soon found that the tool questions could only be solved in close connection with the knowledge of raw materials. Here the demands of the growing requirements of the automobile industry were of the greatest influence. This industry gave the important task to the Research Institute (R.I.) to find the best methods of machining all kinds of steels, of aluminium alloys and of the electron group of light metals. In about five years of constant work this great task has been principally solved and then continuously followed in consequence of the continuous improvements of raw materials and tools from 1908-1933. You have seen the most important periods on some of the lantern slides this evening.

Almost at the same time leading steel works invented (1908) the Cobalt and Molybdenum tool steel alloys and charged the R.I. to investigate the superiority of these components as impartial arbitrator. In making these tests the R.I. found the best cutting conditions for turning and planing tools, twist drills, milling cutters and grinding wheels.

A final consequence was the influence of the knowledge of tool and raw material to the design of machine tools. These have to be made quicker, more rigid, and free from vibrations.

As the leader of the R.I. had worked for a long time in constructing machine tools and had worked since 1904 in favour of the development of these machines, the R.I. got automatically the whole information from three sides—raw material (steel maker), tool, machine tool as the natural place of centre, exploitation and utilisation.

The practical success of the R.I.'s publications in the course of twenty-eight years was the obvious reason for the different indus-

tries to spend sufficient money to finance this industrial research. There were £3,000 to £5,000 per year depending on the importance of the special tasks. The fundamental costs for the building and the first equipment of testing machines and testing apparatus have been given by the Government and partially (as the testing machines) by the machine tool industry, about £20,000. In the following times the means necessary for the support of the R.I. have been given by the Government and the industries together—by the big Associations for general purposes, by private industry for special tasks.

The I. G. Colours attempted to find the best method to machine Electron material by turning, milling, and drilling. The manufacturers of milling cutters had an interest in the best cutting angles of their tools. The biggest German brass and copper mill wanted to know a method, how to separate easily machinable brass bars from too hard ones for automatic screw machines. They had to improve their alloys in the course of this investigation. The ball-bearing industry had comparisons made between plain-ball- and roller bearings. The result gave interesting data on the correct lubrication. In all trials the important correlation between raw material and tool was decisive.

Finally, the Russian Government together with the VDW charged the leader of the R.I. to fix tests and alignments for the inspection of machine tools. This inspection book regulated the dispute and settled some hard fights peacefully, regarding a total delivery of about 300,000,000 gold marks (£15,000,000) in the time from 1925 to 1932.

This task was not at all a formal one, in order to gather the dispersed data of 50 different machines, but was bound to fix the allowable deformations of the machines under load, a research work begun already (1904). R.I. must have the full confidence of all industries to its capacity, experience, and impartiality. This is the base of a fertile collaboration and a necessity for a serious and valuable success.

Mr. W. Symes : This paper is of sufficient importance to merit comparison with the classical researches of Dempster Smith and F. W. Taylor. As far as I am aware it is the only really systematic attack on obtaining data for the performance of tungsten carbide tools., similar to the data provided by the latter in the original investigations into high-speed steels. It is true that the results have been obtained on a simple, standardised range of materials, but this should be no bar to taking advantage of results, because the speeds and feeds for the " in-between " materials can be obtained by interpolation of the curves given.

Some cutting performances with tungsten carbide tools on machine tools of continental manufacture have made some engineers feel that the continental manufacturers are considerably ahead on

machine tool design, the quality of tungsten carbide tools, and the outputs obtained. One such performance was the cutting of 60-ton material at a cutting speed between 500 and 600 ft. per minute, leaving a remarkable finish on the work. The centre lathe on which the cutting was done was capable of a maximum spindle speed of 1,600 r.p.m. In the adoption of much higher speeds the question of dynamic balance of the rotating parts is of importance and was not dealt with in Dr. Schlesinger's remarks.

Another continental development which will have very important bearing indeed is that milling machines are being made with spindle speeds up to 3,000 r.p.m. The feeds per tooth, as recommended by the author, are kept to a comparatively small figure but due to the speed and light feed very good milling rates are obtained. The finish on the softer material such as copper and brass is almost mirror finish.

I was very pleased to note Dr. Schlesinger's advocacy of larger size milling machine arbors, as some ten to twelve years ago I had the greatest difficulty in increasing the size of arbor on some demonstration jobs from 1 in. to 1½ in. to 2 in. In some cases the weakest part of the power transmission lay in the keyways in the arbors and, in one or two instances—mainly in connection with multiple sawing—this has been obviated by using square arbors and square holes in the saws.

Mr. Ingham touched on a vital point when he enquired as to how this research work had been financed. In Britain most of the various industries shelve their research on to their suppliers. As an example the automobile industry has only just started the Research Association for design and had had some difficulty in obtaining the necessary finance amongst the firms most likely to benefit. In another direction there is no organised research into machine tool design and no experiments are at present in progress on a reasonably large scale similar to the investigations reported by Dr Schlesinger. If the machine tool industry in conjunction with the users of its products could get together and start similar investigations into the use of tungsten carbide tools and the higher grades of cobalt steel tools, and also the necessary modifications in machine tool designs to obtain the best from them, the paper would have a most helpful influence on the British manufacturing industry.

Dr. Schlesinger: Mr. Symes remarks on the milling arbor and its best execution are of considerable interest. But it will not be easy to use square holes in the ordinary slab-milling cutter. The sharp corner is the beginning crack. The saw is thin and its diameter mostly great, the square hole may here be used without danger. But it is possible to use the spline shaft for the mandril and the broached hole V for the cutter. In this case the inside of the hole

of the cutter must be kept sufficiently soft in hardening that it can be machined by a specially hard broach.

Regarding the final finish of very fine but softer surfaces by finish-turning, instead of grinding, it must be stated that this is only a question of speed and the life of the cutting edge. In many cases a good finish with tungsten carbide is sufficient. Providing the cutting edge remains sharp and the precision of the machine is sufficiently high, there is no doubt that interchangeable parts can be manufactured by finish-turning (0.01 mm. allowance). Speed and accuracy are the leading features of the modern machine tool construction.

Discussion, Birmingham Section.

Dr. H. Schofield : I have been extremely interested in listening to what Dr. Schlesinger has had to say. I have the advantage in that this is the second time this week that I have had a similar privilege. Only last evening he addressed an audience similar in size to this, and when I tell you that he has repeated nothing of what he said then, you will appreciate something of the application and capabilities of the man who has been addressing us.

My own active association with production engineering goes back to the beginning of the third series that Dr. Schlesinger gave us, and therefore I cannot in any way speak from practical experience of the modern demands which are made upon the machine tool. I can, however, appreciate that there is a need for attention being given to this. It is quite obvious to anyone who is even touching the fringe of the productive industries of this or any other country that we have progressed very much further in our investigation of the cutting materials than we have in our scientific investigation of the machines which are using those cutting materials. I think Dr. Schlesinger has quite rightly pointed out the need for standardisation and investigation of the actual machine tool we are going to use.

Dr. Schlesinger has had unique experience. He has been at this work for some thirty years in Charlottenburg alone, and I do not know whether we realise it, but probably he is the most outstanding man, not only in this country at the present time but in the world, on this subject. A very unique opportunity has been vouchsafed to us to have the privilege of listening to him. I feel myself that the loss of Germany in losing Dr. Schlesinger from Charlottenburg ought to be made into the gain of this country, and I do congratulate the Institution in having brought Dr. Schlesinger here. There are those who hope it may be possible to establish him here in Great Britain on production engineering research in order that he can pursue investigations in that field following on the research in machine tools which he has carried already to such a high degree of proficiency.

As a lecturer of some years standing, one must realise that the Doctor has been speaking to us in a language other than his own, and I wonder how many of us could have conveyed the results of this research in an equally explicit and very pointed way had we been called upon to reverse this proceeding.

Mr. R. C. Fenton (Section Vice-President) : I would like to ask Dr. Schlesinger just one or two things. He illustrated, for instance, research in drills for drilling electron. Can he tell us how

far the machine tool trade in Germany takes note of these experiments, and if it offers different drills for different metals ? Is it the practice of the salesman who offers drills to his customer in Germany to specify different helix angles ?

DR. SCHLESINGER : That has been done. The firm who ordered these tests was I. G. Farben-Bitterfeld. The I. G. Farben published a booklet using these tests as propaganda material of their Electron-Metal, of which Germany consumes a great deal. The firms furnishing the drills did the same. You saw the drill tests on different kinds of steel for the automobile manufacturers. Six firms sent the money to have these tests done. It took about two years to get the necessary data, but then we knew all that was useful as to angles and flutes. The different shapes of drill are now given in the drill catalogues for steel, cast iron, bronze, aluminium, etc. You have to pay more for the special form, but not much. The research will prove of great advantage in automobile shops, where you have mass production in general ; the same in the telephone branch, radio works, etc., at any place where, small drills being used often, when you have single-purpose machines driven at the best speeds.

MR. GEO. WRAY : Dr. Schlesinger gave some experiments on drill performance. I noticed that in his experiments he gets very much higher results than in those lower down which give the German make and English make. Is that due to the source of supply being different from the English and German makes, or is it due to the design of the drill ?

DR. SCHLESINGER : The results refer only to the same kind of German make, furnished by the same producer but executed after different design. In the upper part of the table you had the wrong drill, in the lower part a good drill. I showed two drills. The first drill had a 24° helix angle, and the good drill had 45°. The different angles of the point were 80°, 100°, 120°, and 140°. We found that 120° point by 45° helix gave the best result for this special work. The material (electron), diameter, speed feed, all conditions remained the same, we only varied either the angle of the helix or of the point. If you make tests you must only change *one* variable at a time, else you will never be able to find the influence of the single element. This is the most important rule but it takes time.

MR. WHITE : Has Dr. Schlesinger had any experience of bakelite work ?

DR. SCHLESINGER : Bakelite is generally handled by press-processes. We have investigated hydraulic and friction presses for bakelite. The tools were the same, only the surface was stellited because the bakelite is hard and wearing the ordinary tool. In cutting plate material to make buttons and similar articles we made hollow end-mills (crown shape) of Widia-tips with extraordinary success.

MR. J. W. BERRY: The thoroughness and scope of Dr. Schlesinger's research deserve every ounce of commendation we can give, and I would like to emphasise the note that Dr. Schofield has struck in his remarks on England taking advantage, if at all possible, of the knowledge and the experience which Dr. Schlesinger has. I was in a machine tool manufacturer's in the States ten days ago, and mentioned the name of Dr. Schlesinger. The man immediately knew him, and gave as his opinion that Dr. Schlesinger was undoubtedly the foremost authority on machine tools in the whole world. I do think that if it is at all possible we, as an Institution, ought to try to gain by the experience which Dr. Schlesinger undoubtedly can put at our disposal. It needs money, but I think the British production engineers as a whole will see the value to them of such work because Dr. Schlesinger's knowledge goes much beyond the actual requirements of the machine tool, and he can be of great value to many firms who are interested in manufacture of any description.

MR. WALTON: Dr. Schlesinger seemed no great lover of ball bearings in machine tools, from what I could gather, and I think myself he is right.

DR. SCHLESINGER: The ball bearing question is not yet solved. In the Standards' Sub-Committee on ball bearings for machine tools, tool makers asked for much more accurate ball bearings than are on the market. The ball bearing makers told us: "Yes, you can have them but they will cost considerably more." Especially for the grinding machine elements, internal and external, they must be of a very high degree of accuracy.

It was very interesting to me that the Fortuna Works in Stuttgart, one of the best grinding-machine factories in the world, never took ball bearings from the market but made them themselves. The ball bearing is very good for the grinding machine with its small stresses, but it is generally too weak for the heavier machine-tools and ought to be replaced by roller bearings. High speed and heavy forces at the same time are destructive to the ball bearing.

MR. THORNELOE (Visitor): On one slide there was shown one conical bearing spindle. Dr. Schlesinger passed a remark as to that being the better bearing. (DR. SCHLESINGER: For a lathe). Now, accuracy is one thing, but it is also necessary in production engineering to have machines which will readily be in first class functioning even if you have not got 100% supervision. Is it not very much more difficult to get the best results from a conical bearing? Is there not still a place for a parallel plain bearing efficiently lubricated? In past years, when I was associated with machine tools more intimately, we found we got much better results from a parallel bearing, when efficiently lubricated, rather than a conical bearing. Where there is much end-thrust, the correct adjustment of the coni-

cal bearing is a very serious thing. There are very few people who have the gift for getting the best results from them.

DR. SCHLESINGER : The Timpken bevel roller bearing is very well developed by the firm, and I believe they understand better than any other firm the manufacturing of conical roller bearings. The bearings are adjusted by preloading and this very fact requires a thorough practice. Further the conical bearing gives automatically the adjustment legwise, diminishing the clearance and taking the backlash up, radially and axially, with the same adjustment. If you have a cylindrical bearing you must have a thrust bearing besides with a special adjustment. I showed a section through the front bearing of the Monarch lathe ; the Monarch machine contains a single Timpken bearing in front, and another single bearing on the back of the spindle. If a double Timpken bearing is used this is absolutely rigid and does not give way. This design is not suitable for a lathe, but good for the milling machine. Compare the front bearing at the " Lang " lathe. I believe you are right that the cylindrical bearing is desirable. It is not neceessary to reload it—because you can adjust it at the time of fitting. This problem was solved by the design of the " Verein. Kugellagerfabriken-Schweinfurt," which represents a very interesting cylindrical roller bearing with a solid and still adjustable inner race.

MR. THORNELOE : Excuse my not being sufficiently explicit. I was referring to the plain conical bearing, not to the taper roller bearing.

DR. SCHLESINGER : This was a misunderstanding, I am sorry. The plain conical bearing made by the " Werkzeugmaschinenfabrik Oerlikon "—Switzerland, shown in the slide, has proved sound. Mr. Thorneloe is right to state that its correct adjustment is difficult, but still it is possible. The great advantage is that the bushing in the housing is not split but solid, therefore its seat is never changed and never gets loose. This is of special value with milling machines.

MR. WHITE : You do not make any reference to the coolant used in those tests. Does it make any difference or have any bearing ?

DR. SCHLESINGER : Coolant has a very great influence. With quick-running high-speed steels, such as cobalt steel, cemented tungsten carbide, you ought to have an overflow of coolant leading to the cutting edge specially when machining tough steels. About two to four gallons per minute are sufficient. Special tests were made with and without coolant. The relation of dry to cooled cutting varies between 1 : 2 and 1 : 5 increase of the " life," i.e., cutting minutes of the tool. Therefore you ought never buy a modern turret lathe, a lathe, or a milling machine, without a big tank for the coolant, a good pump, and delivery to the cutting edge.

MR. T. JACOBS : Dr. Schlesinger touched on grinding, about which there has been a good deal of talk in other spheres, and by people who come selling grinding wheels, but when it comes to the use of the grinding wheel they seem to be all at sea. Dr. Schlesinger tells us he has been doing research on grinding. I should like to ask him if he has found out any way of estimating the correct speed at which to run work in conjunction with the speed of the wheel ? I am asking this question because I have been going into this subject for some time myself and I have found that the variation is tremendous. In one case we were getting as much as 20% scrap grinding with a certain machine, an internal grinder. Investigations were set on foot and it was amazing the things they found out. In the first place the motor was heating up very badly and using about 20 amps. instead of 10 : the concentricity of the job could not be be got within .005 in. limit, and rejection was about 40%. We found that by reducing the speed of the work from 265 to 130 we could guarantee the work within .002 in. There was no comparison as to finish, and the amount of electricity was 10 amps., while the wheel lasted about twice as long on one truing up.

Can Dr. Schlesinger say if he has gound anything like that, or if he knows of any means whereby you can specify, when you know the wheel and material and all the conditions, what speed the work should run at, instead of the way it is done at the present time ?

DR. SCHLESINGER : It is difficult to answer this question in a few minutes. I published a book, " *Wirtschaftliches Schleifen* " (economical grinding) with the publisher Julius Springer, Berlin. There you will find a good many examples of useful combinations of speeds and feeds. If you diminish the speed of the workpiece for roughing you are right, but not for finishing. For finishing you must go up to 60, 70, or 80 ft. per minute for the piece and about 90 ft. per second for the wheel. Then you have to adjust the feed very carefully. The John Lund people, Keighley, furnish an astonishing high " black " finish with their machines. Ask Mr. Scaife for exact data. We have done a certain amount of research work some years ago on about 30 different grinding wheels. The results have been published in the " *Forschungsheft* 43 "—Schlesinger, published by the " *Verein Deutscher Ingenieure*," Berlin.

MR. JACOBS : This was in internal grinding, not external grinding.

DR. SCHLESINGER : What kind of work ? Was it wet ? My book on " Economical Grinding " treats both internal and external grinding.

MR. JACOBS : Yes, It was a cast iron brake drum. I will give you another case. An internal grinder was not running as it should. It was a small diameter wheel, 1½ in. in diameter, and the wheel was actually running at 15,000 r.p.m. In our opinion, according to the speed of that wheel, it was impossible for the wheel to do its

work because the cutting edges had not time to cut the work. We reduced it from 15,000 to 10,000 ft., and the consequence was that instead of 15 components we got 90 components. I put this question to the supplier of the wheels and gave him all the conditions, and asked him to specify a wheel and tell me exactly the speed at which the wheel should run. He replied that he could not tell me—all we could do was to keep on trying until we found it. I think it is rather strange that this sort of thing should be going on at the present time.

MR. I. H. WRIGHT (Section President, in the chair): I should like to point out regarding a point that has been made once or twice, that the usual idea of research into a problem in the shop, like that Mr. Jacobs has mentioned, is not research at all. It is simply searching round until you get to something that gets some work out. As Dr. Schlesinger mentioned, the only way to carry out research is to have control of all the main factors of the problem and to vary them one at a time and decide the effect of variations in one thing at a time, and by doing so you can get a grasp of the volume presented by the problem. Only a fully equipped research department can do that. Therefore it is up to the Institution of Production Engineers to do all they possibly can, and use all the influence they possibly can, in the direction of letting us have some research in this particular field. Other branches of engineering have elaborate research institutions and arrangements, but the production engineers and the machine tool makers who are, of course, only their very humble servants, have no research. It is up to you.

MR. R. C. FENTON: I am sure that a vote of thanks to Dr. Schlesinger will meet with universal applause. Dr. Schlesinger has already been engaged upon research work for thirty years, and it is a privilege for us to be allowed to listen to such a very explicit description of the work of which he has carried out the major portion, and which will give a great many of us food for thought. One point which perhaps some of us have not thought about is that a great deal of this research work is extraordinarily tedious, and it requires great patience to carry through tests which last as long as three years, tabulating result after result from the mass of figures which have to be sorted out. Our very sincere thanks are due to Dr. Schlesinger for his efforts to-night.